State of Connecticut.

PUBLIC DOCUMENT No. 34.

FIFTEENTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.,

FOR THE YEAR ENDING JUNE 30, 1903.

PRINTED BY ORDER OF THE LEGISLATURE.

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OF THE

CONNECTICUT AGRICULTURAL COLLEGE.

CONTENTS.

Publications of the Station

AVAILABLE FOR FREE DISTRIBUTION.

THE STORRS AGRICULTURAL EXPERIMENT STATION is located in Mansfield Township, Tolland County, Connecticut, as a department of the Connecticut Agricultural College. The freight and express station is Eagleville, Conn., on the Central Vermont Railroad. The telegraph address is Willimantic, with which city the Station is connected by telephone. Long distance telephone connection brings all points of the State into direct communication with the Station.

The following publications of the Station are available for distribution and will be sent free on request as long as the supply lasts.

All correspondence should be addressed to

STORRS AGRICULTURAL EXPERIMENT STATION,
STORRS, CONNECTICUT.

BULLETINS.

No. 1. Organization of the Storrs School Agricultural Experiment Station and Character of the Work Begun.
No. 5. Atmospheric Nitrogen as Plant Food.
No. 6. Grass and Forage Garden. Grasses and Legumes.
No. 7. Chemistry and Economy of Food.
No. 8. Summary of Annual Report for 1891. Food Investigations. Nitrogen and the Farmer. Forage Crops. Nitrogen of the Air as Plant Food. Fertilizer Experiments on Grass. Field Experiments with Fertilizers by Farmers.
No. 9. Soiling and Soiling Crops. Feeding Experiments with Soiling Crops.
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No. 24. The History of a Tuberculous Herd of Cows.
No. 25. The Covered Pail a Factor in Sanitary Milk Production.
No. 26. The Relation of Temperature to the Keeping Property of Milk.
No. 27. Poultry as Food.

REPORTS.

The Reports of the Storrs Agricultural Experiment Station from the first (1888) to the fifteenth (1902–3) are available for free distribution.

Report of the Executive Committee.

To His Excellency Abiram Chamberlain,

Governor of Connecticut:

In accordance with the resolution of the General Assembly concerning the congressional appropriations to the Agricultural Experiment Stations, and an Act of the General Assembly approved March 19, 1895, relating to the publication of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Fifteenth Annual Report of that Station; namely, that for the year ending June 30, 1903.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year.

Respectfully submitted,

GEORGE A. HOPSON,
B. C. PATTERSON,
GEORGE S. PALMER,

Executive Committee.

*Report of the Treasurer

FOR THE FISCAL YEAR ENDING JUNE 30TH, 1903.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.

United States Treasury,	$7,500 00

EXPENDITURES.

Salaries,	$4,016 54
Labor,	999 48
Publications,	158 78
Postage and stationery,	165 55
Freight and express,	78 91
Heat, light, water, and power,	58 91
Chemical supplies,	86 76
Seeds, plants, and sundry supplies,	294 94
Feeding stuffs,	29 50
Library,	35 20
Tools, implements, and machinery,	2 00
Furniture and fixtures,	154 21
Scientific apparatus,	582 06
Live stock,	80 50
Traveling expenses,	366 76
Contingent expenses,	15 00
Buildings and repairs,	374 90
	$7,500 00

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1903, that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $7,500 and the corresponding disbursements $7,500, for all of which proper vouchers are on file and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress, approved March 2, 1887.

(Signed,) GEO. A. HOPSON, M. M. FRISBIE, } *Auditors.*

STORRS, CONN., July 15, 1903.

*For report of the Director and Treasurer for year ending June 30, 1902, see appendix.

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	33 55
	$1,833 55

EXPENDITURES.

Salaries,	$1,156 23
Labor,	168 79
Postage and stationery,	132 82
Freight and express,	25 42
Heat, light, water, and power,	34 20
Chemical supplies,	122 16
Seeds, plants, and sundry supplies,	129 02
Furniture and fixtures,	3 50
Scientific apparatus,	61 16
Traveling expenses,	25
	$1,833 55

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1903, and that we have found the same well kept and classified as above, and that the receipts for the year from the State of Connecticut are shown to have been $1,800 and the receipts from miscellaneous sources are shown to have been $33.55, making the total receipts from the State and miscellaneous sources $1,833.55 and the corresponding disbursements $1,833.55, for all of which proper vouchers are on file and have been by us examined and found to be correct, thus leaving no balance.

(Signed,) GEO. A. HOPSON, M. M. FRISBIE, *Auditors.*

STORRS, CONN., July 15, 1903.

W. H. HALL, *Treasurer.*

*Report of the Director.

During the past year the Station has been reorganized, and the Director's office has been located at the Connecticut Agricultural College. The entire equipment of the college, so far as it can be used without interfering with college work, has been made available for the Experiment Station work. There are many reasons why it is an advantage to have the Experiment Station connected with the college. The Station alone would be unable to maintain a herd of cows for dairy experiments; it would be unable to maintain an extensive poultry plant which is at its service in connection with the college; and in other respects are the advantages equally evident.

Whenever changes are made in station organization it requires some time to get experiments started along new lines. Various members of the faculty of the Connecticut Agricultural College have given valuable service to the Experiment Station and have furnished for station use notes upon experiments which they have conducted in past years before their connection with the Station. The lines of work which are now in operation have been selected with special reference to the needs of Connecticut agriculture. Every station should have in its work a two-fold object; to discover new truths and to illustrate and emphasize and bring to the attention of the farmers old truths in a practical form. If the Connecticut farmers should all put into practice the best systems which are now known, a great step in advance would be made. It is the duty of the Experiment Station to emphasize the importance of better methods of tillage and economical use of fertilizers, as well as to discover new scientific truths.

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* For report of the Director for the year ending June 30, 1902, see appendix.

NUTRITION INVESTIGATION.

The Station nutrition investigations, under the direction of Prof. W. O. Atwater, have been carried on at Middletown as usual, in coöperation with Wesleyan University and the U. S. Department of Agriculture. The work of the past year has included investigations with men in the respiration calorimeter and a study of the chemical composition and the nutritive value of poultry. An account of the nutrition investigation and discussion of results obtained is given by Prof. Atwater in several articles in this report. An article by Mr. R. D. Milner, discussing poultry as food and the possibilities of poultry raising in Connecticut, is also included.

DAIRY BACTERIOLOGY.

The subject of pure foods is attracting more attention each year, and, as a result, Dairy Bacteriology is recognized as of vast importance. In the production of wholesome milk, and in the manufacture of butter and cheese, bacteria play an important part. We now recognize the fact that certain bacteria are beneficial, and certain others injurious. It becomes, then, the office of the bacteriologist to tell us how the injurious may be done away with or reduced to a minimum, or how we can encourage those bacteria which are our friends. Dr. H. W. Conn has been retained by the Station as Supervisor of the work in Dairy Bacteriology. To properly carry out experiments along this line, a well-equipped laboratory is absolutely essential. The Agricultural College placed at the service of the Experiment Station a large room on the second floor of the Agricultural Hall. This room has been thoroughly equipped as a laboratory for Dairy Bacteriology. Expensive apparatus has been purchased, and a large amount of the Station funds during the past year has been devoted to this work. It seemed the wise policy to equip the laboratory as thoroughly as the funds would permit. For this reason no expense has been

spared in making this laboratory for Dairy Bacteriology a thoroughly efficient one in every way. The Station also has the use of Dr. Conn's laboratory at Middletown, where the work is carried on under his personal supervision. The details of the work in our own laboratory have been directly in charge of Professor Stocking. It is hoped to enlarge somewhat the bacteriological work during the coming year and make a study of soil bacteria and their relation to plant growth. It is purposed to make bacteriological investigation one of the leading features of the Station work.

POULTRY WORK.

The extensive poultry plant of the Connecticut Agricultural College has been in part placed at the service of the Experiment Station. This enables the Station to do much more along poultry lines than it would otherwise be able to do. Interesting experiments are under way, but it should be remembered that these experiments have just been undertaken during the past year, and that time is required to secure results of importance. The poultry industry in Connecticut is one capable of great development. At the present time much of the poultry products which are consumed in this State are shipped from the West. There is no reason why the home market, at least, should not be supplied with home products. A study has been made of the conditions of the markets in Boston and in New York, and it is hoped that the experiments which are already under way and which will be undertaken in the future will do something to encourage the poultry industry in the State.

STOCK FEEDING.

The fine dairy herd of the college has been available for experimental work. For several years past important records have been kept as to cost of food and value of the product, and the results of these experiments will be available for publication by the Station.

HORTICULTURAL INVESTIGATIONS.

Much of the land of Connecticut is admirably adapted to fruit raising. The best markets in the world are near at hand, and the possibilities along the line of fruit growing are very promising. The Assistant Horticulturist of the Experiment Station has direct charge of the work along these lines.

ALFALFA EXPERIMENTS.

In many states alfalfa has come to be recognized as one of the standard forage and hay crops. Where it can be grown successfully, it is of even more value than clover. Up to the present time it has not been generally successful in Connecticut. In a few places, however, it is being grown at the present time. During the past year we have sent out alfalfa seed to some eighty different farmers in the State with directions for sowing the same. We hope to find where alfalfa will grow successfully, and make a careful study of the soils and conditions where it will not grow. If we can succeed in introducing alfalfa as one of the staple crops of Connecticut, it will prove of inestimable value to the dairymen. This work is being conducted in coöperation with the Bureau of Plant Industry of the United States Department of Agriculture.

POTATO EXPERIMENTS.

The potato is one of the leading crops in Connecticut, and it is especially adapted to intensive methods of tillage. As commonly grown in this State, from 1,000 to 2,000 pounds of commercial fertilizer are used per acre. We believe that it is possible by practicing the best methods of tillage to grow this crop profitably and use less commercial fertilizer. Tillage experiments with potatoes will form an important part of the field work in agriculture. The land which is available for experimental work at the present time is in such condition that small plat work is impracticable. The experiments during the

present year are carried on under field conditions and on large areas. The land which in the future will be devoted to plat work must, of necessity, be thoroughly prepared and must be uniformly cropped for a time, so that the individuality of each plat can be ascertained.

Several new lines of work have been taken up by the Station during the past year, and time will be required to secure results of value from these experiments.

FARMERS' INSTITUTES AND OTHER MEETINGS.

During the winter there is a great demand for members of the Station Staff to lecture before the Farmers' Institutes and Grange meetings of the State. We have felt that one thing which is needed is to have the farmers of the State become more intimately acquainted with the men who are doing the Station work. For this reason nearly all requests have been responded to, and a large number of the meetings have been addressed, not only by the Director, but by other members of the staff during the past year. In this way, in part, are the results of Station work brought before the farmers of Connecticut. This work will be continued for the present, even if it draws heavily upon the time of some of the Station workers.

In general the work of the Station has progressed satisfactorily during the past year. Our work in the future will, of necessity, be along a few definite lines, and it will be the aim of the Station Officers to bring the work more and more into direct aid of Connecticut agriculture.

L. A. CLINTON.

Report of the Department of Dairy Bacteriology.

To the Director of Storrs Agricultural Experiment Station:

SIR:—During the last year a very large amount of work upon the problems of dairy bacteriology has been carried on in the laboratory of the Station. This work has been under my general direction but carried on conjointly with W. A. Stocking, Jr., and W. M. Esten, as indicated in the following articles. The general purpose of the work undertaken has been to obtain further information concerning the species of bacteria especially related to dairy problems. The study of numbers of bacteria in milk and its products under various conditions has been carefully pursued for years, until there seems to be little chance for much further important information to be obtained along these lines. Hitherto, however, very little has been done upon the species of bacteria developing in milk under various conditions. It is therefore manifest that the problems of dairy bacteriology must concern themselves, in the future, with *species* rather than simple *numbers*. As pointed out in the report of 1901, a method for the direct qualitative analysis of milk bacteria has been devised in our laboratory, and the work of the last year has been the application to various dairy problems of the methods devised.

The work reported in the following pages included two somewhat distinct series of articles. The first series with Mr. Stocking has involved the study of three questions:

1. The numbers and chief types of bacteria which are found in milk *obtained under different conditions.*

2. The number and chief types of species that are present in milk which has been treated by *different dairy methods.*

3. The number and chief types of bacteria that are present in milk at various intervals when kept at *different temperatures.*

In this series of experiments the analysis of the bacteria was only a general one designed for detecting the chief types of milk bacteria, *i. e.* the per cent. of lactic organisms, of peptonizing forms and of neutral forms; but no close attempt was made at obtaining an accurate analysis of individual species.

The experiments, carried out under the direct work of Mr. Esten, involved a more careful study of the species of bacteria, and the attempt was made to analyze the species present in milk very much more carefully. In this work we have determined the species of bacteria present in the ordinary milk of our markets and so far as possible analyzed these bacteria to the distinct species. The work done along this line showed that the methods adopted were somewhat irregular and in a measure unreliable. This led to a long series of experiments to obtain methods of culture that are more uniform, and the experiments have resulted finally in the adoption of new culture media and new methods of using them. The results of these experiments and the details of the methods now employed in the laboratory are also given below.

In general the papers that are embodied in this report are a part of a series of studies upon the species of bacteria which are associated with and materially concerned in various dairy problems. They represent a continuation of experiments begun a year ago and are still in progress.

Respectfully submitted,

H. W. Conn.

Report of Dairy Husbandman.

To the Director of Storrs Agricultural Experiment Station:

SIR:—I herewith submit a brief outline of the work of the Dairy Department for the year ending June 30, 1903.

Observation and experience with a tuberculous herd of dairy cows extended over a period of several years. The data collected were published in Bulletin No. 24.

In this report may be found records showing the food cost of raising eighteen dairy calves. Nine were raised on skim milk and hay, and nine on a similar ration, but with the addition of a small amount of grain.

Observations were made of the milk flow and butter fat production of cows following dehorning. Tables are given showing the shrinkage as the result of this operation.

The amount of milk secured by different milkers in equal periods from the same cows was ascertained. A score card for judging efficiency in milking has been formulated.

During the past winter two groups of eight cows each were fed, in alternate periods, rations containing the same kind and amount of roughage and the same amount of grain, but of different quality. The two rations contained about 1.5 and 2 pounds of protein respectively. It seems best to repeat this feeding trial before commenting on results.

The effect upon the milk flow, following the application of "fly repellants" to dairy cows, was investigated last summer. The work will be continued during this season.

At the present time an experiment to ascertain the comparative food value of milks of different quality is in progress.

Various substitutes for milk and skim milk in raising dairy calves have been tried the past winter. The trials thus far have been unsatisfactory, but this work will be continued.

Respectfully submitted,

CHARLES L. BEACH.

Report of Horticulturist.

To the Director of Storrs Agricultural Experiment Station:

SIR:—As the Experiment Station has not yet been reorganized a year, a full season's work cannot be reported upon, and most previous work of the department was done without regard to the formation of a Station.

The department has, however, much material gathered on the college grounds that will soon be available for tree fruit variety tests, as well as in other lines of work that would take time to produce results, if prepared specially for the purpose.

The possession of a cold storage plant enabled us to make some tests of varieties of apples for storage purposes. Some experiments were also made in apple thinning by the department previous to the formation of the Station. The results of all of this work are given in full in the report of the Assistant Horticulturist in connection with that of other experiments that he has undertaken. My own time has been largely devoted to my regular college duties.

Respectfully submitted,

A. G. GULLEY.

Report of the Assistant Horticulturist.

To the Director of Storrs Agricultural Experiment Station:

SIR:—Since taking up the work of the department January 1st, 1903, investigations have been carried on with cold storage apples to determine the length of time different varieties could be kept after being taken from the cold storage. Also some work was done during the winter with apples to determine the cause of "cold storage scald." No direct results were obtained, but it is thought advisable to do more work along the same line this coming winter.

Extensive operations in spraying for San Jose scale were carried on under the direction of the department in the orchard of J. H. Hale at South Glastonbury, Conn., during March and April. This work was done to determine the cost and efficiency of the sulphur, lime, and salt solution as a remedy for San Jose scale, when applied in large orchards. A detailed account of this work is given elsewhere in this report.

Work with cucumbers and melons to test the advisability of spraying with Bordeaux mixture for blight has been started and will continue through the season.

Notes on new varieties are being kept with strawberries and tomatoes, and notes on the blossoming and fruiting periods of the orchard fruits have been kept for the Pomological Department at Washington.

Respectfully submitted,

E. R. BENNETT.

Report of the Poultryman.

To the Director of Storrs Agricultural Experiment Station:

SIR:—Although the poultry industry in Connecticut is of vast importance to our citizens, the Storrs Agricultural Experiment Station has given it no attention prior to the year just closing. The work of the Poultry Division during the past few months has, therefore, been largely preliminary to the experimental work we desire to carry on.

Some work has been accomplished in the cost of feeding breeding ducks and also the cost of rearing ducklings to market age. Much valuable data has been secured, which will be of great advantage in the somewhat extended experiment we desire to make along the same line next season.

In view of the very decided interest being taken in the possibilities of market squab production, it has been deemed advisable to investigate this comparatively new industry. A flock of fine homing pigeons has recently been secured, and permanent quarters are now being prepared for them. There is no doubt that the work with these interesting birds will be carefully watched by people all over the country.

In order that the work of this division be carried on in the most satisfactory manner, it will be necessary to secure more modern buildings and appliances. A large proportion of our population is directly interested in the poultry industry, and it is plain to all careful observers that this interest is steadily growing. The writer believes, therefore, that with proper equipment the Poultry Division can be made of decided value to the State at large.

Respectfully submitted,

F. H. STONEBURN.

Report of the Consulting Veterinarian

To the Director of Storrs Agricultural Experiment Station:

SIR:—The Veterinary Department of the Station not being a regular division of the organization, but only a "consulting," has in consequence no report on regular routine work. During the past year many letters of inquiry with reference to diseases, etc., of domesticated animals and fowls have been answered. This branch of work occupies some little time, but on the whole is very satisfactory to all parties concerned, and therefore the time seems well spent.

Early in the spring (1903) a case of nitrate of soda poisoning in West Stafford, Conn., was brought to the attention of the department. Three post mortems were performed, and from the pathological changes noticed irritant poisoning was diagnosed. On investigation, it was shown that nitrate of soda had been fed to the animals for coarse salt. The animals died inside of eight hours from the time of feeding the nitrate of soda.

Another interesting case investigated was that of an outbreak of malignant catarrh in a herd of cattle in Middlefield, Conn. This case was brought to the attention of the department by H. O. Averill, State Cattle Commissioner. Out of a herd of forty or fifty cattle, mostly "springers," some eighteen succumbed before the nature of the disease was finally ascertained. All that can be done in this disease is along the line of prevention; *i. e.*, isolation, disinfection, etc. The latter measure was carried out very thoroughly with excellent results. The disease is not believed to be contagious; that is, it is not a germ disease and cannot be transmitted from one animal to another, but is supposed

to be miasmatic, or caused by some poison in the air. Some experiments were conducted along the line of inoculation and germ culture, but all results, however, were decidedly negative.

Another item of interest in the past year's work is the experiment in the treatment of milk fever (parturient apoplexy) with oxygen gas injected into the udder. But one case was treated. This one, however, gave such evident good results from the treatment that it is our opinion that here is a positive remedy for this fatal disease.

Respectfully submitted,

E. H. LEHNERT, D. V. S.

DAIRY BACTERIOLOGY LABORATORY.

BY W. A. STOCKING, JR.

The officers of the Storrs Experiment Station were among the first to recognize the importance of the subject of bacteriology in its relation to the dairy and the work and problems of the dairymen. For some years the Station has given a part of its attention to this field of investigation and experimentation. Previously the work has been hampered because of inadequate laboratory facilities, but at the beginning of the present year Director L. A. Clinton decided to strengthen this line of work by equipping a new laboratory which should meet the requirements of the work, and for this purpose several hundred dollars of the Station funds have been expended. This laboratory is located on the third floor of Agricultural Hall and occupies the entire north end of the building, with windows on the east, north, and west. The laboratory consists of three rooms, which may be designated as follows:

Room No. 1. This might properly be termed the kitchen of the bacteriological laboratory, since it is in this room that the glassware and other utensils are washed, the sterilizing done, and the culture media made. The room is fitted with a sink which has running water supplied by a tank above. Live steam is brought from the high pressure boiler in the creamery below and is used here for heating water and for sterilizing certain of the utensils used. At the end of the sink is a large draining table covered with zinc. In this room is located the dry air sterilizer which can be seen standing on the end of the table in Fig. 1. This is used for sterilizing all of the

glassware that is used in the laboratory. The laboratory is not at present supplied with gas, owing to lack of funds, and heat is furnished for this sterilizer by three Primus stoves, which burn vaporized kerosene. These give an intense heat, without odor, by which the sterilizer can be heated to 160° C. In this room is also located the steam sterilizer which can be seen near the left of the picture. This is used for sterilizing

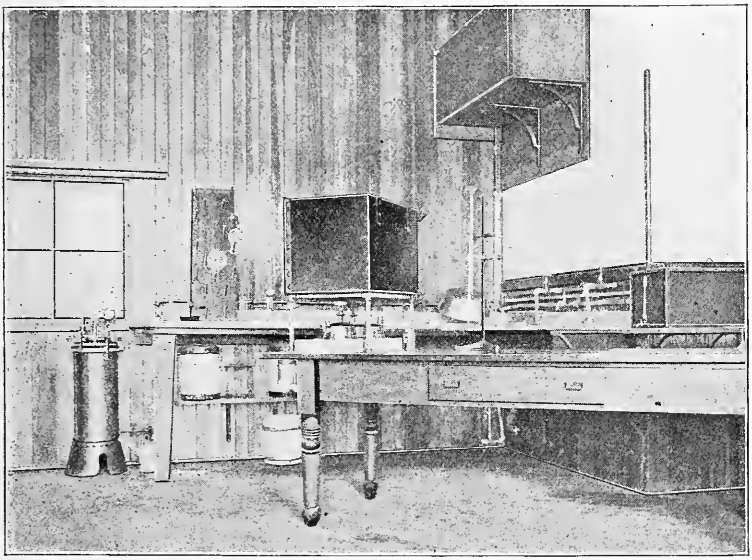

FIG. 1.

ROOM NO. 1. DAIRY BACTERIOLOGY LABORATORY.

the liquids such as water, milk, and the various culture media which are used in connection with this work. This sterilizer is connected with the high pressure steam boiler and can be run at any desired pressure. This room is also fitted with a large closet in which is stored the clean glassware away from the dust. There is also in one corner a small dark closet for the storage of certain materials which need to be kept from the light.

Room No. 2. The most essential part of a bacteriological laboratory in which accurate work is to be done is the dust-proof room where plate cultures may be made and various organisms transferred from one receptacle to another with the least possible danger of contamination from external bacteria and moulds. The atmosphere in an ordinary room, especially if there is any draught, is liable to be filled with bacteria and mould spores. A picture of this room will be seen in Fig. 2.

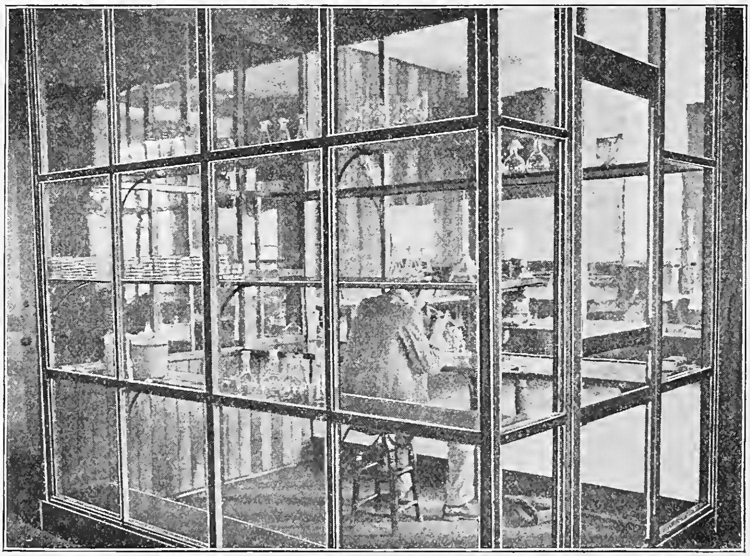

Fig. 2.

Room No. 2. Dust-proof Room of Dairy Bacteriology Laboratory.

This dust-proof room is six by eight feet in size, entirely of glass set in putty so that dust cannot enter. The room is well supplied with shelves for the storage of sterilized glassware. In this room cultures may be made with very little danger of external contamination.

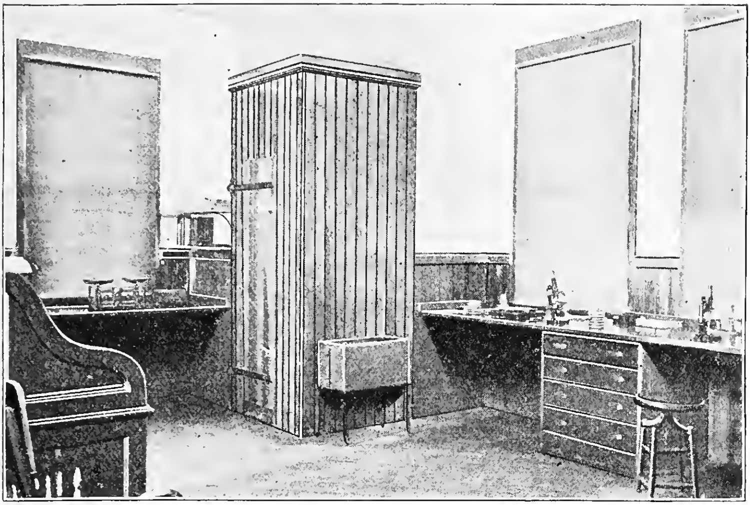

FIG. 3.
COLD STORAGE CHAMBER OF DAIRY BACTERIOLOGY LABORATORY.

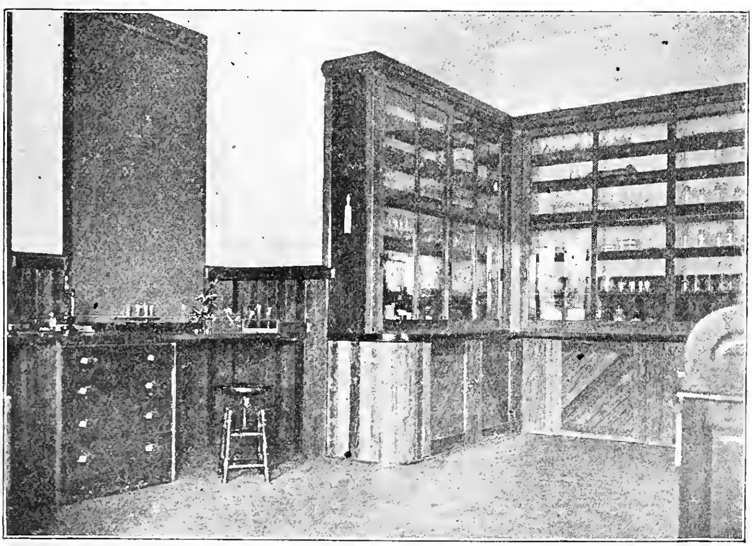

FIG. 4.
STORAGE SHELVES FOR GLASSWARE IN DAIRY BACTERIOLOGY LABORATORY.

Room No. 3. Sections of this room can be seen in Figs. 3 and 4. This room is practically the same size as No. 1 and is fitted with glass cases in which glassware may be stored away from the dust. This room is separated from room No. 1 and can be kept quite cool; and it is in this room that most of the real investigation work is done.

Standing on the table in Fig. 3 may be seen a new Bausch & Lomb microscope purchased during the year for the bacteriological department at a cost of about $80. While this instrument is not fitted with some of the fine attachments which might be desirable, it has most of the adjustments which are needed for the work of the Station and is a very good instrument. Toward the left of Fig. 3 may be seen the torsion balances, which are used for weighing coarse materials, and, at the extreme left, one end of the office desk, which stands with its back against the dust-proof room. This room has windows on both the east and the north, which furnish suitable light for microscopic work during the entire day.

In Fig. 3 can be seen a small cold storage chamber, which is connected with the refrigerator plant in the creamery below. Some of the culture materials used must be kept below a certain temperature in order to prevent spoiling; and since these temperatures are below the ordinary room temperatures during warm weather, a place in which they can be kept cold is a necessity. This cool chamber furnishes such a convenience without the expense of using ice. It is also very serviceable in connection with experiments in which cold temperatures are desired for keeping milk.

In Fig. 5 will be seen a small balance room, in which is placed a pair of Becker's short arm chemical balances used for fine weighing. Beyond the balance room, at the left end of the picture, may be seen a door leading to the photographic room, which is well equipped for photographic work. These two

rooms stand next to the bacteriological laboratory proper and will be used in connection with both the bacteriological work and the soil physics laboratory, which is located on the same floor.

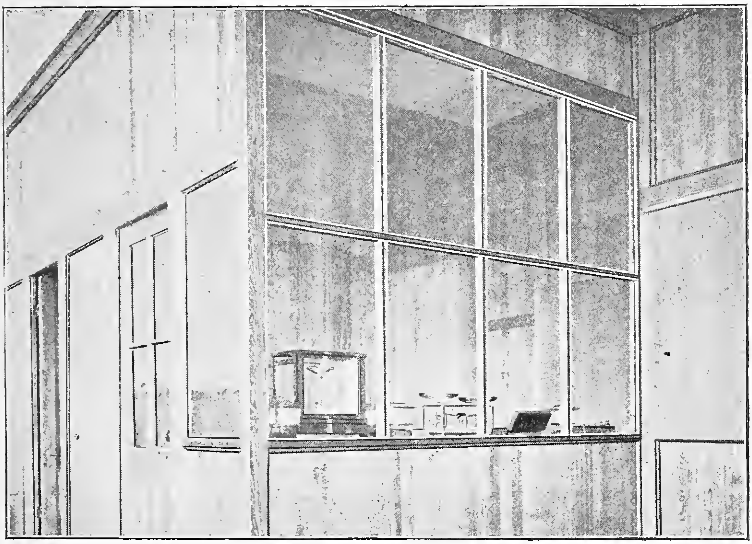

FIG. 5.
BALANCE ROOM.

THINNING FRUIT.

BY E. R. BENNETT.

In thinning fruit, one or more of four benefits may be expected to result: (1) Maintaining the vigor of the tree; (2) producing fruit of maximum size, appearance, and quality; (3) securing annual crops instead of alternate; (4) preventing the spread of parasitic diseases.

Vigor and thrift of the tree is one of the first essentials in producing and maintaining a good orchard. To obtain this end everything must be avoided that will tend to retard the natural, regular growth. When a tree is developing a heavy crop of fruit, it makes very little, if any, growth of wood, and seldom produces fruit buds for the following year. These facts are indications that the vital energy of the tree has been overtaxed, and one or two years are required to get back the normal vigor of the tree. Not infrequently trees die from the effects of overbearing. At best the exhaustion caused by overbearing leaves the tree in poor condition to withstand the attacks of hard winters and insect enemies and fungous diseases.

Overbearing is often a source of trouble with young trees. There is a well known rule among stock breeders that no animal should be allowed to produce young until it has reached a certain stage of maturity. This law is applicable to plants as well as to animals. Some varieties have a tendency to bear very young. *Abundance* plums bear while in the nursery row and are in consequence short lived. Trees with this habit should be thinned very severely at first, and the amount of fruit increased gradually from year to year until the tree is developed.

Thinning fruit to increase its size and improve its appearance has been carried on to a limited extent for a long time. This work has mostly been done to produce fruit for show purposes or for a fancy trade. It is generally understood that while thinning does increase size and improve the appearance and

quality, the expense of having the work done is so great that it cannot be made to pay with ordinary fruits that are to be sold in the open market. A well known writer on the subject, from whom we quote, expresses the prevailing opinion when he says, "It will not pay to thin all classes of fruit. Only early or fancy varieties of apples will reward the cultivator for the expense and labor of thinning."

It is true that all varieties of fruit do not respond to thinning alike. *Lombard* and *Japanese* varieties of plums respond quickly to thinning, the results being a large increase in size and improvement in quality; while the *Damson* type of plums does not show any very marked difference in size and quality between the thinned ones and the unthinned.

As to the advisability of thinning standard varieties of apples that are to be sold in open market, some experiments carried on by Profsssor A. G. Gulley in the orchards of the Connecticut Agricultural College at Storrs, Conn., will throw some light on the subject.

Five medium sized *Baldwin* trees in a good state of thrift and with as near the same conditions as possible were selected. No. 1 in the table had no check, Nos. 2 and 3 were practically the same size, as were also Nos. 4 and 5. Nos. 1, 2, and 4 were thinned, leaving Nos. 3 and 5 as checks. The thinning was done July 15th, 1902, at which time it took 20 apples to make a quart. The early dropping was over, so there was no danger of leaving too few apples on the trees. On No. 1, according to estimate, one-third were taken off; on No. 2, one-fourth; while on No. 4 the thinning was mostly done on heavy-laden limbs. These trees had been previously sprayed for apple scab and codlin moth, so that the subsequent dropping caused by these troubles was light; but Nos. 3 and 5 dropped the most.

The apples when picked were graded by the rules of the Apple Buyers' Association; *i. e.*, 1st grade, 2½ inches or over in diameter, 2nd grade, 2 to 2½ inches. It should be noticed that while all the apples were undersized or only fair-sized, the firsts in Nos. 3 and 5 required more apples to the barrel than did the thinned fruits. Especially is this true of No. 3, where 570 were required to the barrel as against 536 of No. 2. Had the thinning been carried further on Nos. 2 and 4, it is probable that larger apples would have resulted.

TABLE I.

No. of Tree.	Total No. Apples.	Number Thinned.	Number No. 1.	Number No. 2.	Barrels No. 1.	Barrels No. 2.	Number in Bbls. No. 1.	Number in Bbls. No. 2.	Value of Fruit on each Tree.	Value of each Barrel.	Time used in Thinning.
											Hrs.
1	4075	1260	2440	375	$4\frac{15}{21}$	$\frac{16}{25}$	529	725	$6.25	$1.19	2
2	6270	1450	3615	1205	$6\frac{21}{25}$	$1\frac{16}{25}$	536	755	9.80	1.15	$2\frac{1}{3}$
3	5605	—	1710	3895	3	$5\frac{11}{25}$	570	755	7.62	$.93\frac{1}{3}$	—
4	4900	925	2825	1150	$5\frac{10}{25}$	$1\frac{16}{25}$	530	710	8.00	$1.13\frac{1}{2}$	$1\frac{1}{2}$
5	4160	—	2190	1970	4	$2\frac{16}{25}$	547	750	7.00	1.05	—

The usual objection to thinning—that it takes too much time—is hardly worth considering when we figure the difference in value between the product of the thinned and the unthinned trees. The cost of thinning No. 4 was 22½ cents, and the difference in value between the product of the two trees was $1.00, a gain for the thinned tree of 77½ cents. On No. 2 the cost of thinning was 35 cents, and the difference in value between the product of this tree and that of No. 3 was $2.18, a difference of $1.83 in favor of the thinned tree.

Another important point should not be lost sight of. Dividing the fruit into grades is an operation which takes considerable time, especially when most of the apples are close to the dividing line. No record was made of the time required to sort the fruit of the thinned and the unthinned trees, yet it was a noticeable fact that much more time was required to grade apples from the unthinned trees, owing to the large per cent. of apples that were a little too small to go as first grade. It was thought that the time saved in grading the thinned fruit would about make up for the time spent in thinning.

Thinning to Produce Annual Bearers.—The tendency to produce a crop of fruit on alternate years has become so fixed with some varieties that they are known as alternate bearers. Whether this is a natural or acquired characteristic is an open question. We have no proof that such varieties as *Baldwin* or *Northern Spy* would not have been annual bearers, had a judicious system of thinning been followed from the origin of these varieties. It is not probable that at this time any amount

of thinning could change the habit of these old varieties to any great extent, but with such varieties as *Wealthy*, *Dutchess of Oldenberg*, or any of the other new, heavy-bearing varieties, there is every reason to think that by rigid and successive thinning, year after year, they could be induced to bear as readily one year as another.

Thinning to Prevent the Spread of Parasitic Diseases.—When brown rot *(Monilia Fructigenum)* is working on green or ripening fruits, the rot starts on the side that is most protected from the sun and wind, or in other words where there is the most moisture. The rot is spread by spores that are borne by the wind to places of lodgment in some crevice between fruits, or between a fruit and a bunch of leaves or other protection where enough moisture is present to start the spore into growth, somewhat as a seed is germinated. After the rot once gets started, it will spread from fruit to fruit until all the fruit on the tree has been destroyed, if, as is the case frequently with plums, the fruits are close enough to touch one another. Large fruits should not be allowed to grow in bunches, as the chances are much better for one single fruit to escape the ravages of brown rot than for two or more that are in contact. The same is true of apples. While there is less danger that brown rot will affect apples, the codlin moth is afforded a protection from sprays in a cluster of apples and can work with little danger of being troubled by poisons or by his bird enemies.

How to Thin.—No fast rule can be laid down for thinning all fruits. There is very little danger of thinning too much, the tendency usually being not to thin enough. Peaches should be thinned until the individual fruits are six to eight inches apart. Plums should not be left close enough so that they will touch one another when full grown. A good rule is to leave them so that the space between them will be three times the diameter of the fruits at maturity. Thinning apples is somewhat more difficult than thinning the other fruits, yet when the operator has become familiar with the work, it can be carried on much more rapidly than would be supposed. Some mechanical devices for thinning fruit have been tried, but they have not been successful, because of the difficulty of discriminating between the good and the inferior fruits. The best

method is to hand-pick the fruits that are not wanted on the trees.

A good plan is to remove all discarded fruit from the orchard, either burning or burying it, as these fruits contain many partly developed codlin moth larvae, curculio, and other insects. Discarded peaches and plums, if left under the trees, furnish a medium for the development of rots.

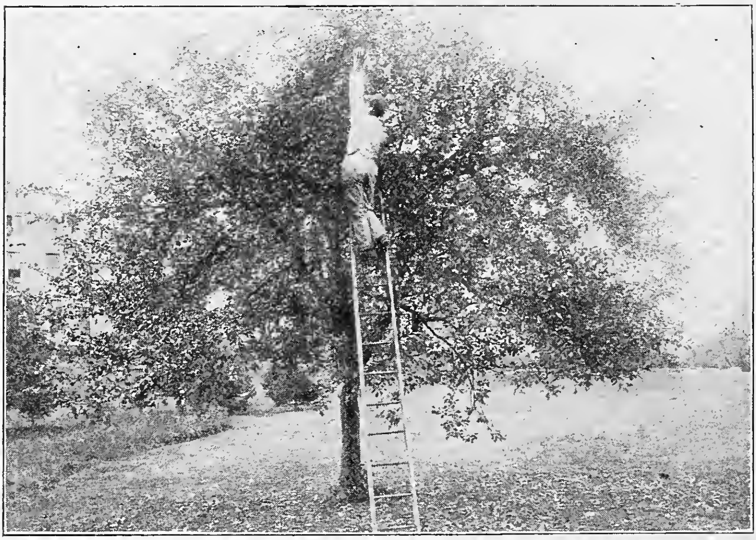

FIG. 6.

THINNING APPLES.

When to Thin.—In general, the earlier thinning is done the better. The ideal time to thin is when the trees are in blossom; but unfortunately this is impossible, as at that time we have no method of telling from the number of blossoms how much fruit is going to develop. The time differs somewhat with different species of fruit. Usually it is not wise to thin until after the earlier periods of falling are past, which, in the northern states, is from the middle of June to the middle of July. The general care of the trees has much to do with the falling of fruit, fewer fruits falling from trees that are well sprayed and cared for than from neglected trees.

COMPARISON OF BACTERIA IN STRAINED AND UNSTRAINED SAMPLES OF MILK.

H. W. CONN AND W. A. STOCKING, JR.

In the experiments described in the last annual report, it was noted that milk which had been strained or had passed through a centrifugal, although containing smaller numbers of bacteria than the milk that had not been so treated, quite frequently soured and curdled quicker than the normal milk. The first series of experiments here reported was designed for the purpose of testing somewhat carefully the effect of straining milk upon the number of bacteria and upon the keeping property of the milk. The method of experimenting was as follows:

Milk was drawn from individual cows in an ordinary open pail, and after the cows were completely milked a sample of the milk was obtained. The milk was then strained through two layers of sterilized cheese cloth, and a second sample obtained in the same way. Both samples were taken to the laboratory, and four plates in litmus gelatin made from them immediately. Both were then placed at a temperature of 70°, and after 50 hours a second series of plates was made, and the amount of acid present in the milk was determined. The milk was then left at the same temperature until the time of curdling, at which time a third series of plates was made, and a third test of the amount of acid. In some experiments the milk curdled during the night, and this last series of tests could not be made.

In all cases at least four plates were made, and the results tabulated represent an average of the samples. In studying the plates after proper growth, the total number of bacteria was determined, the number of lactic organisms as indicated by the production of acid in litmus gelatin, and the number of peptonizing forms as indicated by the liquefaction of the gelatin. The results were determined both in numbers and in percentages.

The following table represents the results of this series of experiments.

TABLE 2.

Comparing strained and unstrained samples. Milk kept at 70°.

		Fresh.				At Fifty Hours.					At Curdling.		
		Total Number of Bacteria.	Acid Bacteria. Number.	Acid Bacteria. Per Cent.	Number of Liquefying Bacteria.	Total Number of Bacteria.	Number of Acid Bacteria.	Per Cent. of Acid Bacteria.	Number of Liquefying Bacteria.	Per Cent. of Acid.	Per Cent. of Acid Bacteria.	Per Cent. of Acid.	Hours.
1	Open, - -	3,950	1,375	34	537	196,000,000	195,000,000	99	1,437,000	.41	100—	—	51
	Strained, -	4,712	1,775	38	750	623,000,000	595,000,000	96	11,500,000	.50	99+	.75	58
2	Open, - -	2,825	1,500	53	487	330,000,000	—	—	—	.42	99	.66	55
	Strained, -	3,300	1,700	53	587	490,000,000	488,500,000	100	1,500,000	.39	100—	.67	55
3	Open, - -	9,275	4,350	47	300	38,000,000	31,000,000	80	7,685,000	.25	97	.76	73
	Strained, -	8,700	4,162	48	262	24,000,000	21,000,000	91	2,125,000	.23	98	.70	82
4	Open, - -	1,625	540	33	125	1,891,000,000	1,888,000,000	100	2,500,000	.80	—	—	42*
	Strained, -	1,837	837	46	187	1,192,000,000	1,191,000,000	100	1,750,000	.77	—	—	42*
5	Open, - -	9,012	725	9	1,112	626,000,000	624,000,000	100	1,415,000	.53	—	—	59
	Strained, -	2,850	537	19	187	274,000,000	271,000,000	99	2,800,000	.26	—	—	65*
6	Open, - -	12,500	2,125	17	1,200	151,000,000	148,000,000	98	2,800,000	.28	—	—	102
	Strained, -	10,725	1,650	15	900	68,000,000	65,000,000	95	3,125,000	.23	—	—	103
7	Open, - -	28,325	8,525	30	1,212	64,000,000	32,000,000	50	4,625,900	.21	—	—	65*
	Strained, -	27,900	7,750	28	1,287	98,000,000	84,000,000	96	337,000	.22	—	—	65*
8	Open, - -	3,512	1,062	30	137	389,000,000	388,000,000	100	—	.30	100—	1.15	99
	Strained, -	2,750	587	21	187	396,000,000	396,000,000	100	166,000	.28	—	1.23	122
9	Open, - -	44,200	6,600	15	1,150	338,000,000	—	—	500,000	.32	—	—	65*
	Strained, -	48,266	7,300	15	916	444,000,000	—	—	875,000	.32	100—	.80	50
10	Open, - -	28,000	9,750	35	625	484,000,000	—	—	125,000	.36	100—	.72	77
	Strained, -	25,250	2,565	10	1,050	376,000,000	376,000,000	100	250,000	.30	100—	1.00	104
Av.	Open, - -	**13,743**	**3,523**	**30**	**679**	**450,000,000**	**400,000,000**	**89**	**7,358,000**	**.39**	**99**	**.82**	**68**
	Strained, -	**13,005**	**2,703**	**28**	**617**	**398,000,000**	**386,000,000**	**97**	**2,652,000**	**.35**	**99**	**.83**	**72**

* Milk curdled during the night; exact time not determined.

The study of the figures given in this table shows only a few points of especial interest, but particular attention may be called to the following points:

1. When the averages of the strained and unstrained samples are compared together, it will be seen that there is very little difference in the time of curdling. In these experiments the strained samples curdled actually, on an average, four hours earlier than the unstrained samples; a difference which is certainly noticeable, but is hardly enough to be regarded as of any especial importance.

2. It will be seen that the rapidity of curdling varies very widely, the shortest being 42 hours and the longest 104 hours. The samples, it will be remembered, were all retained *at the same temperature of 70°*, and this difference in time of curdling is somewhat surprising. It would be anticipated that the difference in the time of curdling under such conditions would be found due to the difference in numbers of bacteria that were present in the original milk. An examination of the table, however, shows that this was not the case. The sample which curdled in the shortest time, namely No. 4, had actually the smallest number of bacteria of any of the samples tested, only 1,625 bacteria per cubic centimeter; whereas the sample in experiment No. 10 that curdled in 104 hours had 28,000 bacteria, which is very nearly the largest number that was present in the whole series. It will be noticed also that in experiment No. 10, whereas the numbers of bacteria in the strained and in the unstrained samples were not very different, there was a difference of about 27 hours in the time of curdling, a fact for which no explanation can at present be given.

3. The average numbers of bacteria in the strained and in the unstrained samples are practically the same, indicating that straining has no especial influence in removing the bacteria. In comparing the actual experiments in the table it will be found that sometimes the strained samples and sometimes the unstrained gave the larger numbers, and that there was a great irregularity in this respect.

4. From the column giving the percentage of acid bacteria it would appear that a larger percentage of acid bacteria is present in the unstrained than in the strained samples, suggesting

that the straining has a tendency to remove a relatively larger number of lactic bacteria. The difference, however, is only 2 per cent. and is probably not large enough to have any significance.

5. The comparison of the amounts of acid present in the samples after 50 hours shows that, in general, the development of acid is parallel with the number of bacteria. The samples having the largest amount of acid at 50 hours have large total numbers of bacteria, while those that have small amounts of acid have small numbers of bacteria. While this parallel is apparent, it is not very close, and noticeable irregularities appear.

6. The number of bacteria present at the end of 50 hours seems to be totally independent of the number present at the outset. If experiment No. 4 be compared with experiments No. 3, this will be seen. In the first experiment the number of bacteria present at the outset was 1,625, and the number present in 50 hours was 1,800,000,000; on the other hand, in experiments No. 3 the numbers at the outset were 8,000 and 9,000 respectively, while at the end of 50 hours there were only 24,000,000 and 38,000,000 bacteria found. In experiment No. 9 it will be seen that the milk at the outset contained 44,000 bacteria, next to the largest of any of the tests, while at the end of 50 hours the number was 338,000,000, only about one-sixth as many as in experiment No. 4, which at the outset had only 1,600 bacteria. A further examination of the figures in the two columns will show that no relation can be established between the number of bacteria in the fresh milk and the number present at the end of 50 hours. This fact is very surprising, considering that the milk was kept under identical conditions.

7. The milk kept for 50 hours always contained high percentages of lactic bacteria, as shown by the table. The percentage of lactic bacteria was usually from 90 to 100 per cent., although in one case it dropped to 50 per cent. The percentage of lactic bacteria in the fresh milk in all cases was far lower than this, ranging from 9 per cent. to 53 per cent. in individual cases.

8. At the time of curdling, it will be seen, the percentage of lactic bacteria has in all cases approached very nearly to 100 per cent., one sample giving as low a percentage as 97, but most of them being 99 to 100. This was found to be the case in all of the numerous experiments which we have carried on in the last two years. The species of bacterium is usually *Bact. lactis acidi (No. 206).*

9. At the time of curdling the actual number of bacteria found showed the greatest irregularities. This is not indicated in the table, but, briefly, the number found varied from 211,-000,000 bacteria per cubic centimeter in one single case to 2,700,000,000 bacteria. These numbers had no relation, so far as could be seen, to the time of curdling.

10. The amount of acid present in the milk at the time of curdling showed somewhat surprising variations. In most cases it was from .6 to .8 per cent.; but in one case it was 1.15, and in the other sample of the same date, 1.23. The reason for this wide difference in the amount of acid present at the curdling point we cannot at present explain.

SERIES II. STRAINED AND UNSTRAINED MILK PRESERVED AT 70° AND 50°.

H. W. CONN AND W. A. STOCKING, JR.

As shown in the preceding series of experiments, some of the results obtained were not uniform, and there seems to be no general relation between the numbers of bacteria in fresh milk and the numbers which were found at certain later periods. We deemed it desirable, therefore, to test somewhat more extensively this relation between the bacteria at the two stages in the ripening of the milk. A new set of experiments was planned, somewhat similar to those of the previous set, except that they were broadened in certain respects and designed to give further data.

The chief purpose of these experiments was to determine more accurately: 1. Whether any relation exists between the number and kind of bacteria present in the fresh milk and at a later period. 2. Whether straining of the milk through cheese cloth has any influence upon the bacteria, either in the fresh milk or in the milk at later periods. 3. Whether any definite relation can be established between the number of bacteria present and the development of acid in the milk. 4. Whether a change in the temperature affects the relative number of different types as well as the total number of bacteria found. Certain other individual results appear in the course of the experiments.

The method by which this new series of experiments was pursued was as follows: One cow was selected for experiment, and all of the following observations were made upon the milk of the same cow. The milk from this cow was drawn into an ordinary open pail. It was then very thoroughly stirred, and two samples were taken in sterilized bottles, one of which was kept at a constant temperature of 70° F., and the other at a temperature of 50° F. The rest of the milk was then strained

TABLE 3.

Bacteria in milk from open pail. Samples kept at 70°.

Date.	Bacteria in Fresh Milk.				At Fifty Hours.					Hours to Curdling.
	Total.	Acids.	Per Cent. Acids.	Liquefiers.	Total Bacteria.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.	Per Cent. Acid.	
December 28, - - - - - -	9,100	1,200	13	737	368,000,000	367,000,000	100-	1,000,000	.30	78
					1,161,675,000	**1,161,050,000**	**100-**	**625,000**	—	—
December 31, - - - - - -	9,662	2,025	21	887	1,030,000,000	1,029,975,000	100-	250,000	.63	55
January 2, - - - - - - -	13,300	1,917	14	1,067	114,875,000	112.500,000	99	2,375,000	.29	107
January 7, - - - - - - -	17,467	1,100	06	2,433	291,000,000	289,000,000	99	4,500,000	.31	86
					961.562.500	**960.312.500**	**100-**	**625,000**	—	—
January 9, - - - - - - -	4,316	2,166	50	466	1,439,687,500	1,439,218,750	100-	468,750	.58	56
January 11, - - - - - -	6,187	3,250	52	112	85,375,000	84,125,000	99	500,000	.31	75
					1,284,300,000	**1,283,850,000**	**100-**	—	—	—
January 14, - - - - - -	4,450	1,862	42	175	278,665,000	277,165,000	99	1,500,000	.33	137
January 16, - - - - - -	2,900	433	15	—	199,000,000	197,625,000	99	750,000	.26	124
					389,625,000	**388,500,000**	**100-**	**1,750,000**	—	—
January 18, - - - - - -	1,575	700	44	75	282,750,000	282,500,000	100-	250,000	.26	65
Average, - - - - - -	7,662	1,628	29	661	454,372,500	453,234,305	99	1,288,194	.38	87

TABLE 4.

Bacteria in strained milk. Samples kept at 70°.

Date.	Bacteria in Fresh Milk.				At Fifty Hours.					Hours to Curdling.
	Total.	Acids.	Per Cent. Acids.	Liquefiers.	Total Bacteria.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.	Per Cent. Acid.	
December 28,	9,475	1,400	15	850	450,875,000	450,625,000	100–	375,000	.31	64
December 31,	7,725	2,300	30	900	1,025,125,000	1,025,000,000	100–	—	.63	55
January 2,	11,433	1,567	14	1,217	187,333,333	165,333,333	88	2,000,000	.28	129
January 7,	12,567	833	7	1,300	325,037,500	322,500,000	99	3,750,000	.33	95
January 9,	3,612	1,312	36	425	947,898,750	946,248,750	100–	131,250	.48	65
January 11,	5,600	3,250	58	100	234,250,000	207,875,000	89	1,125,000	.35	98
					474,062,500	**473,750,000**	**100–**	**625,000**	—	—
January 14,	4,533	2,466	54	216	353,000,000	352,750,000	100–	250,000	.32	141
January 16,	725	316	44	50	*	—	—	500,000	.24	113
January 18,	1,700	667	39	67	*	—	—	—	.24	110
Average,	6,374	1,568	33	569	503,359,940	495,761,726	95	903,472	.35	97
Per cent. removed,	17	4	14†	14	11†	9†	4	30	8.00	11†

* Discolored by alkaline colonies.
† Per cent. increase.

TABLE 5.

Bacteria in milk from open pail. Samples kept at 50°.

Date.	Bacteria in Fresh Milk. Total.	Acids.	Per Cent. Acids.	Liquefiers.	At Fifty Hours. Total Bacteria.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.	Per Cent. Acid.	Hours to curdling.
December 28,	8,400	2,025	24	825	5,250,000	3,125,000	59	500,000	.20	302
					905,375,000	**903,375,000**	**100–**	**2,000,000**	—	—
December 31,	9,187	1,825	20	725	Dilutions were too great to give reliable results in these two tests.				.24	231
January 2,	12,400	2,400	19	1,100					.19	224
January 7,	14,866	1,000	7	1,533	Destroyed by rapid liquefiers before ready to count.				.19	233
January 9,	3,316	1,200	36	362					—	233
January 11,	5,575	3,950	71	162					.19	315
					47,250,000	**45,000,000**	**95**	**1,000,000**	—	—
January 14,	5,700	3,575	63	300	4,000,000	2,531,250	63	218,750	.21	267
January 16,	1,316	450	34	66	4,625,000	3,375,000	73	467,750	.18	420
					155,500,000	**150,500,000**	**97**	**1,750,000**	—	—
January 18,	1,597	700	44	87	11,566,667	undistinguishable	—	33,333	.19	540
Average,	6,929	1,903	35	573	6,360,417	3,010,417	65	304,958	.20	307
Average at time of curdling,					**369,375,000**	**366,291,667**	**97**	**1,583,333**	—	—

TABLE 6.

Bacteria in strained milk. Samples kept at 50°.

Date.	Bacteria in Fresh Milk.				At Fifty Hours.					Hours to curdling.
	Total.	Acids.	Per Cent. Acids.	Liquefiers.	Total Bacteria.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.	Per Cent. Acid.	
December 28,	8,462	1,162	19	892	5,025,000	2,375,000	47	500,000	.20	279
					1,659,375,000	**1,657,500,000**	**100**	**2,187,500**	—	—
December 31,	8,800	2,062	23	1,062	Dilutions were too great to give reliable results in these two tests.				.23	243
January 2,	12,775	2,567	20	1,475					.19	308
January 7,	11,250	1,150	10	1,400	Plates destroyed by rapid liquefiers before ready to count.				.19	257
January 9,	3,512	1,300	37	475					—	257
January 11,	6,575	3,800	58	150					.19	268
					282,500,000	**222,250,000**	**79**	—	—	—
January 14,	4,033	1,870	46	416	4,541,250	2,791,250	61	207,500	.21	435
					70,750,000	**69,000,000**	**97**	**1,750,000**	—	—
January 16,	1,137	437	38	62	4,468,750	3,218,750	72	612,500	.18	219
January 18,	2,087	800	38	37	9,233,333	7,900,000	86	66,667	.19	411
					520,000,000	**519,500,000**	**100**	**500,000**	—	—
Average,	6,516	1,683	32	663	5,817,083	4,071,250	67	346,667	.20	297
Average at time of curdling,					**633,156,250**	**617,062,500**	**94**	**1,109,375**	—	—
Per cent. removed,	6	12	9	16†	9	35†	3	14†	0	3
Per cent. removed,					**71†**	**68†**	**3**	**43**	—	—

† Per cent. increase.

through a strainer made of two thicknesses of cheese cloth supported upon fine wire gauze. Two more samples were taken of this strained milk, which were kept like the first, one at 70°, and the other at 50° F. The four samples were immediately taken to the laboratory, and a series of plates made from them. They were then placed at the temperature above indicated and allowed to remain for 50 hours. At the end of 50 hours a second set of plates was made from each of the four samples. A portion of the milk was also removed for the determination of the amount of acidity present. The samples were then once more placed at their respective temperatures and allowed to remain until they soured and curdled. At the time of curdling, if this occurred in the day time, a third series of plates was made, and a third test of the acidity. If the curdling occurred in the night, it was impossible to make these final observations. The acid was obtained by Farrington's alkaline tablet solution, as in previous experiments.

The results of this series of experiments are given in the preceding tables. In Tables 3 and 4 are given the figures obtained from the samples of milk kept at 70° F., Table 3 giving the unstrained sample, and Table 4 the strained sample. In each of these tables, where the numbers were obtained at the time of curdling they are given in bold faced type. In Tables 5 and 6 are given the similar results in the samples of milk which were kept at 50°, Table 5 being the unstrained sample, and Table 6 the strained sample.

The following general conclusions from these tables may be pointed out.

FRESH MILK.

1. *The effect of straining upon the germ content of fresh milk.*—The first column in the tables gives the total number of organisms found, and a comparison of Tables 3 and 4 will show the effect of straining in removing bacteria. It will be seen that in the majority of cases a certain proportion of the bacteria was removed from the milk by straining. As shown by these two tables, there appeared to be an average of 20 per cent. of the bacteria which was thus removed. An examination of the same columns in Tables 5 and 6 shows, however, a smaller per cent. removed by straining; only 5 per cent. in

this case. Tables 3 and 4 and Tables 5 and 6 represent the same milk, and this difference in results shows the difficulty of obtaining uniform analyses. In both there is a small difference in favor of straining. But the difference is not very large, particularly in the second case, and cannot be regarded as very significant. The conclusion to be drawn from these tables, taken with Table 2, is that straining milk through cheese cloth does have a slight effect of removing the bacteria.

It is something of a surprise that no larger benefit is shown, for, as has been indicated by previous experiments, the amount of dirt which is removed by the straining is about 40 per cent. It would have been expected, therefore, that the removal of so much dirt would remove a larger proportion of the bacteria than the experiments seem to indicate. Furthermore, it is seen that in some of the samples the strained milk contained more bacteria than did the same milk before straining. This is shown, for example, upon December 28, January 14, and January 18. The differences in these cases were not very great, and possibly not greater than the limits of error would permit, but certainly in these cases the strained milk showed more bacteria in the plates than the unstrained milk did. This result, however, is not very surprising, since similar results have been obtained by others. It has been found by Weil (Milchztg 1901, p. 739) that filtering milk through filters frequently increases the apparent number of bacteria present. This author, however, concluded that the cause of the apparent increase was that the filter was not sterilized and contained bacteria which were washed through by the filtering. This does not apply to our experiments, inasmuch as the filter, being simply cheese cloth, was thoroughly sterilized before each experiment. The probable explanation of the result is the condition of the bacteria existing in the milk. A microscopical examination shows that the bacteria of milk have a tendency to group in little clumps. Each of these clumps would, as a rule, result in showing a single colony upon the gelatin plate, with no indication of the number of bacteria present in the group. When the milk is forced through the strainer under the influence of the stream of milk from the pail, these clumps are more or less broken up. The result is a larger count of colonies, although, of course, there is no increase in bacteria.

At all events, the conclusion from these facts is that the straining of milk through cheese cloth, while it removes a considerable portion of the dirt, has no considerable influence upon the number of bacteria present.

2. *Effect of straining upon the acid bacteria compared with the non-acid species.*—The effect previously mentioned, that centrifugalized or strained milk frequently sours quicker than milk not thus treated, suggested that possibly the straining removed a larger number of the non-acid bacteria, leaving in the milk the acid bacteria in greater proportion. This might explain their somewhat more rapid growth and the quicker curdling. To test this conclusion we have made a determination of the number of acid bacteria in the four samples of milk before and after straining, and also a determination of the number of non-acids. At the same time a separate determination of the liquefying bacteria was made. The second, third, and fourth columns in the tables give the results. It will be seen that there is a great variation in the number of acid bacteria found in milk from day to day, even samples from the same cow showing wide differences. For example, on Jan. 16, in Table 4, we find that the milk contained 316 acid bacteria per cubic centimeter, while on Jan. 11 there were 3,250. Taking tests close together, the differences were also great. On Jan. 7, Table 4, we find 833 acid bacteria, while two days later there were 1,312, and two days later still, 3,250. The per cent. of acid bacteria which was removed by straining was smaller than the total per cent. of bacteria removed, in the samples given in Tables 3 and 4, while in Tables 5 and 6 this relation was reversed. If, however, we compare the percentage of acid bacteria in strained and unstrained samples in all four tables, it will be seen that in the majority of cases (ten samples against seven) the strained milk contained a higher per cent. of acid bacteria than did the same milk before straining, although the average of the whole showed little difference. This fact suggests at first sight that the non-acid bacteria are more likely to be removed by straining than the acid producing organisms, a fact further confirmed by the work upon aseptic milking described on a later page, and that possibly here may be the explanation of the more rapid curdling of such samples.

Whether or not the straining does have any such influence upon the relative proportion of the acid and non-acid bacteria, it was evident from further study that this had nothing to do with the rapidity of curdling, for the following reasons. In most cases, at least, the acid producing species which were found in the fresh milk did not continue to grow in the milk for a very long time, but after a few hours they had entirely, or almost entirely, disappeared. By the time the milk was 50 hours old the acid bacteria which were present in the original milk had in most cases almost disappeared, and *another type of lactic bacterium* had become very abundant and undoubtedly produced the souring and curdling. This species is the common acid organism, *Bac. lactis acidi*. It was present in the fresh milk in small numbers only and frequently could not be found at all; but in the milk that was 50 hours old and milk that was ready to curdle it was present in far the greatest numbers. Beyond question the curdling was due to the development of *Bac. lactis acidi*: Since, therefore, the acid species which were found in the *fresh milk* did not develop to any great extent during the souring, it was clear that the relative proportion of acid and non-acid bacteria in fresh milk had little or nothing to do with the rapidity of curdling. In other words, the presence of a considerable number of acid bacteria in fresh milk is no indication of the keeping quality of the milk, nor is it an indication as to the kind of lactic bacteria which will be found in the milk at a later period.

MILK KEPT FOR 50 HOURS AT 70°.

1. *Total number.*—The study of the bacteria found in the milk at the end of 50 hours, in Tables 3 and 4, shows that in a majority of cases the strained samples contained at the end of 50 hours a somewhat larger number of organisms than did the corresponding unstrained samples. The difference, however, was not sufficient to have any meaning (503,000,000 against 454,000,000).

2. *Comparison of the number of acid bacteria in fresh milk with the number in milk 50 hours old.*—A study of column 6 in Tables 3 and 4 shows that the acid bacteria increased very greatly in relative proportion during 50 hours at 70°. In nearly every case milk which was 50 hours old contained bacteria of which 99 per cent. of the total number were acid bacteria. Usually these bacteria consisted of *Bac. lactis acidi* in large percentage, even though this species was found only in small numbers in the fresh milk. Such a large proportion of acid bacteria, of course, left the percentage of non-acid organisms at 50 hours very small. In a few samples the presence of acid producing organisms at 50 hours seems to be somewhat less in the strained samples than in those which were not strained, but the difference is too slight to have any significance. It will also be noticed that in the samples where the acid organisms were few the number of liquefying bacteria was rather high. From this the conclusion is reached that straining the milk has no influence whatsoever upon either the total number or the percentage of acid bacteria that may be expected in the milk after it has been kept for 50 hours at 70°.

3. *Development of acid.*—In column 9 is shown the amount of acid which was present in the milk at 50 hours. It will be seen from this column, first, that even in cases where the acid bacteria at 50 hours had reached 99 per cent., the amount of acid present in the milk was not increased very greatly. The highest per cent. of acid was obtained on Dec. 31,* when there was .63 per cent. at 50 hours. In other cases the percentage of acid was comparatively small; for example, on Jan. 16 and 18 the amount of acid was only .26 per cent. at 50 hours, even though the milk contained at the time 199,000,000 and 282,750,000 bacteria per cubic centimeter respectively, of which lactic bacteria constituted 99 per cent. of the whole. This fact suggests that the production of acid takes place rapidly only after the acid organisms have gained full control of the milk. Further examination of column 9 in Tables 3 and 4 shows that the effect of straining is practically nothing. It is true the average per cent. of acid in Table 3 is slightly greater than in Table 4, .38 per cent. against .35 per cent., but this difference is so slight as to have no meaning; and when the individual experiments in the two tables are compared with one another, it is seen that

* Table 3.

the amount of acid is just as likely to be greater in the strained sample kept at 70° as in the unstrained sample. In short, straining has no effect upon the development of acid.

4. *The effect of straining upon the development of acid bacteria.*—The total number of acid bacteria was practically the same in the strained and unstrained samples after they had remained at 70° for 50 hours. The averages were 453,000,000 in the unstrained and 495,000,000 in the strained samples, the difference between the two numbers not being sufficient to have any significance.

6. *The relation of the production of acid to the development of acid bacteria.*—In these tables it will be seen that in general the milk samples with the highest per cents. of acid show a larger number of acid bacteria than do those with a smaller per cent. of acid.

MILK KEPT FOR 50 HOURS AT 50°.

1. *Total numbers.*—A most striking effect seen in these tables is the result of the temperature of 50° upon the total number of bacteria. It was to be expected that the number would be somewhat smaller than at 70°, but the difference is larger than would be supposed. The average number of bacteria in these samples at the end of 50 hours was 6,000,000. The average number in the samples kept at 70° was very nearly 500,000,000.

2. *The effect of 50° upon growth of acid bacteria.*—The effect of the lower temperature in reducing the development of the acid bacteria was even greater than its effect in reducing the total number. Not only was the number of acid bacteria very much less in these samples than in the samples at 70°, but the *percentage* of acid bacteria was decidedly less. The average percentage of acid bacteria in the samples kept at 70° was, as we have seen, nearly 99; the average percentage of acid bacteria in the samples kept at 50° for 50 hours was about 66. This interesting fact is what might be expected from results previously published. The great development of bacteria in milk after 24 hours is, as we have shown elsewhere, due chiefly to the development of lactic organisms. The lower temperatures, which check the development of bacteria, have

their chief effect upon lactic bacteria, which do not grow so rapidly as the other forms, and thus at the end of 50 hours are not only less in absolute numbers, but also less in relative abundance than in milk kept at 70°.

3. *The effect of straining.*—These tables show as little value in straining as was shown in Tables 3 and 4. If Tables 5 and 6 are compared with each other, it will be seen that the strained samples contained at 50 hours slightly larger average numbers of acid bacteria than did the unstrained samples; and also that the per cent. of acid was very slightly lower in the strained than in the unstrained samples. The difference, however, is too slight to have any meaning.

4. *The development of acid.*—In the column giving the development of acid it will be noticed that during this 50 hours growth at 50° there was only a very slight increase in the amount of acidity. The acidity in the original milk averaged about .18 per cent. In the 50-hour milk kept at 50° the average, it will be seen, is only .20 per cent., there being thus almost no increase in the amount of acidity during this time. This is extremely interesting, taken in connection with the fact that there has been such an immense increase in the number of acid bacteria. Table 5, for example, shows that in the fresh milk there was only an average of 1,903 acid bacteria, whereas in the 50-hour milk the number of acid bacteria averaged 3,000,000. In spite of this immense increase in numbers the increase in acidity was almost inappreciable. The suggestion from this is that the development of the acid in milk is not the direct result of bacterial growth, but occurs only later, after the acid organisms have taken full possession of the milk and have come to compose a large part of the organisms present.

5. *The effect of 50° upon time of curdling.*—The most remarkable and significant result shown by this table is the effect of the comparatively slight lowering of temperature upon the keeping property of the milk. In Tables 3 and 4, with the temperature at 70°, it required 87 and 97 hours respectively to produce a sufficient acidity of the milk to curdle it. A lowering to 50° produced a very unexpected increase in the keeping power. It will be seen from Tables 5 and 6 that

the milk at 50° kept, on an average, about 300 hours before it was sufficiently acid to curdle. The difference in the keeping power of the strained and unstrained samples was not sufficiently great to have much significance, although the unstrained samples kept in these experiments, on an average, about ten hours longer than the strained samples. If the figures are compared a little more closely, the curious fact is brought out that the time of curdling of the milk when it is kept at 50° appears to be quite unrelated to the number of bacteria present at the outset. For instance, from Table 6 it will be seen that the sample of Jan. 2 contained nearly 13,000 bacteria, the largest number in fresh milk in the whole series. But at 50° this milk kept 308 hours, somewhat longer than the average. The sample of Jan. 16 contained in the fresh milk the smallest number of bacteria in the whole series, only 1,137, but this sample kept the shortest time of all, curdling in 219 hours. A further study of the tables and a comparison of the first column with the last column bring out clearly the fact that in milk kept at 50° the number of hours that elapsed before the milk was ready to curdle is quite unrelated to the number of the bacteria present in the fresh milk. The practical conclusion that is to be drawn from this for guidance in the handling of milk is that, for the purpose of increasing the keeping properties of the milk, the question of *temperature is of primary importance* and has far more significance in determining the keeping property of milk than has the extent of the original contamination. This result holds for all samples of milk where the number of bacteria is moderate, ranging from 1,000 or more to 20,000 or 30,000 per cubic centimeter. Whether the same lack of parallelism holds in cases where the milk is excessively contaminated or where it is exceptionally clean, is studied by experiments to be described in the third section of this article.

6. *Number of bacteria at the time of curdling.*—In the four tables it will be seen that about half of the samples curdled in the daytime, and consequently the number of bacteria at the time of curdling could be determined. The other half it was impossible to study, for reasons indicated. Only a few conclusions can be drawn from the figures which are shown in bold faced type in the tables. It will be noticed that the number of

bacteria which are present at the time of curdling is subject to the widest variations, being in some cases as low as 282,000,000 and in other cases as high as 1,659,000,000; in one case more than five times as great as in the other. The amount of acidity which was present at the time of curdling is not given in the tables. It was also somewhat variable, ranging from .68 to .87 per cent., and was about the same in samples where the number of bacteria was very large as where it was comparatively low. From these figures, however, no conclusions of importance can be drawn.

From this series of experiments the most important conclusions are: 1. That straining through cheese cloth, while it removes a considerable quantity of the dirt, has practically no effect upon the keeping property of the milk. 2. A decrease of twenty degrees, from 70° to 50°, makes a most extraordinary difference, (a) in the rapidity of bacteria growth, (b) in the species of the bacteria that grow in the milk, and (c) in the keeping property of the milk, increasing the latter most surprisingly. Milk kept at 70° in these experiments was sour enough to curdle in about two days and a half, while milk which was kept at 50° remained in some cases 20 days or more before it was sufficiently acid to curdle. In connection with the last point it should be stated, however, that although this milk kept without curdling for 20 or more days, this cannot be interpreted as meaning that the milk was fit to use for this length of time. A bacteriological examination of such milk, which was made, showed that the number of bacteria present in these old non-curdled samples was extremely great, far greater than any number given in the tables. But for some reason, which we have not yet explained, the development of the acid organisms had not taken place in such a way as to cause the curdling of the milk.

SERIES III. ASEPTIC MILK.

H. W. CONN AND W. A. STOCKING, JR.

In the two series of experiments above reported one of the most surprising facts was the lack of any parallel observable between the numbers of bacteria present in the fresh milk and the numbers which were found at later periods—at 50 hours or at the time of curdling. Even though the samples of milk were kept at the same temperature and under conditions which were, so far as could be determined, identical, it was quite impossible to reach any conclusion as to the number of bacteria which would be present at the end of 50 hours from the number present at the outset. The numbers in the fresh milk in the experiments already reported varied from 725 to 48,000 per cubic centimeter, and the number present in 50 hours varied from 32,000,000 to 1,800,000,000. The larger numbers in the later periods were not found in the milk that had larger numbers at the outset, but, as already pointed out, frequently just the contrary was true. This result, for which we could suggest no explanation, appeared to need further experimenting; and the question arose whether, if the number of bacteria could be reduced still lower, the same general results would be found. In other words, if milk could be secured which contained only a very small number of bacteria, would such milk contain at the end of 50 hours bacteria in numbers equal to those in milk obtained under less satisfactory conditions and containing at the outset more bacteria? Incidentally the experiments on this line would be of practical value in giving facts concerning the keeping property of aseptic milk. The series of experiments next undertaken, therefore, were designed for the purpose of comparing ordinary milk with milk obtained under exceptional precautions and kept with the same care.

The method of experimenting was as follows. The milk from a single cow was used in all these experiments. One day this milk was drawn into an ordinary open pail without extra

precautions to exclude dirt or bacteria; the next day the milk was drawn under the following aseptic conditions: The cow's tail was tied to the leg on the farther side, and the flank, the side, and the udder were washed with a 3 per cent. solution of boracic acid and wiped with a sterilized cloth; the milker then washed his hands with the boracic acid solution and wiped them on a sterilized cloth. About half of the milk was milked out, and the udder and surrounding parts were again washed with boracic acid and wiped with a sterilized cloth. Once more the milker washed his hands and then drew the remaining milk into a sterilized, covered pail through four thicknesses of sterilized cheese cloth and a layer of absorbent cotton. This milk we call *aseptic milk.*

From the milk obtained in each of these ways, two samples were taken, one of which was kept at 70°, and the other at 50°. Plates were made from all four samples of milk immediately and also at the end of 12, 24, and 36 hours. The percentage of acidity was determined at the same time that the plates were made. The results are given in the following four tables. It will be noticed that at certain of the tests no results were obtained, due in some cases to the presence of liquefiers which destroyed the plates, and in other cases to the unexpectedly small number of bacteria, which led to too high dilutions of the plates.

TABLE 7.

Bacteria in ordinary milk. Samples kept at 70°.

Date.	Total.	Acid Bacteria.	Per Cent. of Acid Bacteria.	Liquefying Bacteria.	Per Cent. of Acid.	Hours to Curdling.
Fresh Milk.						
January 20, - -	3,000	787	26	125	.19	—
January 23, - -	11,217	533	5	17	.20	—
January 27, - -	437	187	43	0	.20	—
February 27, -	3,125	1,300	42	62	.17	—
March 3, - -	5,825	463	8	275	?	—
March 6, - -	2,725	1,188	44	50	.20	—
March 12, - -	888	288	32	100	.18	—
Average, - -	3,888	678	19	90	.19	—
At 12 hours.						
January 20, - -	14,000	9,400	67	250	?	—
January 23, - -	15,267	11,400	75	233	.21	—
January 27, - -	74,200	72,200	97	150	.20	—
February 27, -	25,238	7,225	29	50	.17	—
March 3, - -	46,700	3,200	7	1,000	.19	—
March 6, - -	23,400	1,950	94	300	.20	—
March 12, - -	32,813	5,625	17	750	.18	—
Average, - -	33,088	18,714	55	390	.19	—
At 24 hours.						
January 20, - -	4,477,500	4,472,500	100–	5,000	.21	—
January 23, - -	4,687,500	4,687,500	100	0	.21	—
January 27, - -	?	?	—	88,750	.20	—
February 27, -	?	?	—	?	.16	—
March 3, - -	7,717,500	?	—	12,500	.19	—
March 6, - -	25,500	251,250	99	0	.20	—
March 12, - -	129,100,000	?	—	116,600	.18	—
Average, - -	29,247,500	3,137,083	100–	37,153	.19	—
At 36 hours.						
January 20, - -	149,000,000	149,000,000	100–	50,000	.26	99
January 23, - -	360,000,000	359,000,000	100–	0	.28	50
January 27, - -	891,000,000	891,000,000	100–	1,500,000	.41	52
February 27, -	179,000,000	54,000,000	30	250,000	.20	90
March 3, - -	206,500,000	?	?	125,000	.21	99
March 6, - -	?	?	?	—	?	90
March 12, - -	349,000,000	349,000,000	100–	125,000	.22	74
Average, - -	356,000,000	360,000,000	86	341,667	.26	79

Table 8.

Bacteria in aseptic milk. Samples kept at 70°.

Date.	Total.	Acid Bacteria.	Per Cent. of Acid Bacteria.	Liquefying Bacteria.	Per Cent. of Acid.	Hours to Curdling.
Fresh Milk.						
January 21,	663	412	62	162	.21	—
January 24,	100	13	13	37	.21	—
January 29,	325	50	15	25	.20	—
January 31,	37	25	68	0	.18	—
February 28,	175	125	71	25	.17	—
March 5,	138	56	40	13	.18	—
March 7,	125	50	40	13	.17	—
March 13,	93	?	—	3	.20	—
March 15,	850	585	69	255	.18	—
Average,	**267**	**165**	**47**	**59**	**.19**	—
At 12 hours.						
January 21,	975	650	67	150	.21	—
January 24,	400	125	31	0	.20	—
January 29,	1,712	687	40	25	.20	—
January 31,	13	13	100	0	.18	—
February 28,	1,150	?	—	—	.17	—
March 5,	256	113	44	25	.18	—
March 7,	?	?	—	?	?	—
March 13,	137	19	14	31	.18	—
March 15,	?	?	—	?	.18	—
Average,	**663**	**268**	**49**	**39**	**.19**	—
At 24 hours.						
January 21,	354,500	346,000	98	8,580	.21	—
January 24,	140,000	133,000	95	1,666	.20	—
January 29,	6,566,000	6,557,000	100−	11,250	.20	—
January 31,	2,450	2,433	99	0	.18	—
February 28,	100,000	5,200	5	3,350	.17	—
March 5,	150,000	125,000	83	50,000	.18	—
March 7,	?	?	?	?	?	—
March 13,	137,000	2,550	2	2,500	.18	—
March 15,	1,960,000	152,000	8	17,125	.18	—
Average,	**1,176,325**	**915,498**	**61**	**11,799**	**.19**	—
At 36 hours.						
January 21,	15,250,000	14,887,500	98	112,500	.22	113
January 24,	13,375,000	12,875,000	96	0	.22	53
January 29,	10,125,000	9,200,000	91	75,000	.21	133
January 31,	?	?	?	?	.18	73
February 28,	41,800,000	600,000	1	50,000	.18	153
March 5,	43,500,000	8,000,000	18	75,000	.18	138
March 7,	?	?	?	?	?	162
March 13,	28,350,000	375,000	1	200,000	.19	125
March 15,	233,975,000	?	—	775,000	.20	66
Average,	**55,196,400**	**7,656,250**	**51**	**183,929**	**.20**	**113**

TABLE 9.

Bacteria in ordinary milk. Samples kept at 50°.

DATE	Total.	Acid Bacteria.	Per Cent. of Acid Bact.	Liquefying Bacteria.	Per Cent. of Acid.	Hours to Curdling.
Fresh Milk.						
January 20,	3,950	800	20	487	.19	—
January 27,	412	200	49	13	.20	—
February 27,	7,133	3,000	42	50	.17	—
March 3,	?	?	?	?	?	—
March 6,	3,362	525	16	300	.20	—
March 12,	725	75	10	63	.18	—
Average,	**3,116**	**920**	**27**	**183**	**.19**	—
At 12 hours.						
January 20,	1,613	800	49	150	?	—
January 27,	1,180	483	41	83	.20	—
February 27,	22,500	—	—	50	.17	—
March 3,	6,800	1,070	16	513	.18	—
March 6,	2,188	517	24	225	.20	—
March 12,	2,013	600	30	138	.18	—
Average,	**6,049**	**694**	**32**	**193**	**.19**	—
At 24 hours.						
January 20,	13,550	12,850	95	100	.20	—
January 27,	3,500	?	—	?	.20	—
February 27,	4,850	1,450	40	50	.17	—
March 3,	92,000	6,500	7	1,333	.18	—
March 6,	15,250	12,625	83	1,625	.20	—
March 12,	3,867	933	24	133	.18	—
Average,	**22,170**	**6,872**	**50**	**648**	**.19**	—
At 36 hours.						
January 20,	140,933	139,400	99	1,533	.20	315
January 27,	?	?	?	?	.20	194
February 27,	82,875	14,750	18	1,925	.18	306
March 3,	?	?	?	?	.18	234
March 6,	?	?	?	?	?	171
March 12,	80,750	14,000	17	1,250	.18	138
Average,	**101,519**	**56,050**	**45**	**1,569**	**.19**	**226**

TABLE 10.

Bacteria in aseptic milk. Samples kept at 50°.

Date.	Total.	Acid Bacteria.	Per Cent. of Acid Bacteria.	Liquefying Bacteria.	Per Cent. of Acid.	Hours to Curdling.
Fresh Milk.						
January 21,	363	255	70	37	.21	—
January 24,	112	13	12	0	.21	—
January 29,	487	125	26	13	.20	—
January 31,	25	13	52	7	.18	—
February 28,	175	88	50	19	.17	—
March 5,	143	50	35	6	.18	—
March 7,	31	6	19	6	.17	—
March 13,	70	30	43	0	.20	—
March 15,	775	270	35	290	.18	—
Average,	**242**	**94**	**38**	**42**	**.19**	—
At 12 hours.						
January 21,	437	225	51	0	.21	—
January 24,	19	13	68	0	.20	—
January 29,	337	137	41	37	.20	—
January 31,	25	13	52	13	?	—
February 28,	1,224	?	—	?	.18	—
March 5,	250	75	30	16	.18	—
March 7,	?	?	—	?	?	—
March 13,	38	13	34	0	.18	—
March 15,	575	125	22	75	.18	—
Average,	**363**	**86**	**43**	**20**	**.19**	—
At 24 hours.						
January 21,	1,000	500	50	50	.21	—
January 24,	50	25	50	0	.20	—
January 29,	400	200	50	100	.19	—
January 31,	13	13	100	0	.18	—
February 28,	537	100	19	0	.18	—
March 5,	312	150	48	0	.18	—
March 7,	?	?	—	?	?	—
March 13,	200	13	7	25	.18	—
March 15,	45,416	15,412	34	325	.18	—
Average,	**5 991**	**2,052**	**45**	**63**	**.19**	—
At 36 hours.						
January 21,	3,600	2,400	67	850	.20	113
January 24,	1,450	1,400	97	0	.21	1,300
January 29,	866	500	58	0	.19	360
January 31,	25	25	100	0	.18	197
February 28,	9,000	200	2	0	.19	485
March 5,	375	162	43	12	.18	258
March 7,	?	?	—	?	?	?
March 13,	4,300	900	21	412	.18	301
March 15,	?	?	?	?	.18	186
Average,	**2,802**	**798**	**55**	**182**	**.19**	400

TABLE 11.

Summary of averages.

	Total.	Acid Bacteria.	Per Cent. of Acid Bact.	Liquefying Bacteria.	Per Cent. of Acid.	Hours to Curdling.
Fresh Milk.						
Aseptic at 70°, - -	267	165	47	59	.19	—
Ordinary at 70°, - -	3,888	678	19	90	.19	—
Aseptic at 50°, - -	242	94	38	42	.19	—
Ordinary at 50°, - -	3,116	920	27	183	.19	—
At 12 hours.						
Aseptic at 70°, - -	663	268	49	39	.19	—
Ordinary at 70°, - -	33,088	18,714	55	390	.19	—
Aseptic at 50°, - -	363	86	43	20	.19	—
Ordinary at 50°, - -	6,049	694	32	193	.19	—
At 24 hours.						
Aseptic at 70°, - -	1,176,325	915,498	61	11,799	.19	—
Ordinary at 70°, - -	29,247,500	*3,137,083	100–	37,153	.19	—
Aseptic at 50°, - -	5,991	2,052	45	63	.19	—
Ordinary at 50°, - -	22,170	6,872	50	648	.19	—
At 36 hours.						
Aseptic at 70°, - -	55,196,400	7,656,250	51	183,929	.20	113
Ordinary at 70°, - -	356,000,000	*360,000,000	86 (100)	341,667	.26	79
Aseptic at 50°, - -	2,802	798	55	182	.19	400
Ordinary at 50°, - -	101,519	56,050	45	1,569	.19	226

* Average made from smaller number of tests than for total number; see Table 7.

From these tables the most significant facts to be drawn are as follows:

FRESH MILK.

1. The value of these aseptic precautions in reducing the number of bacteria in the fresh milk is very evident. Milk drawn in these experiments in the ordinary way had in one set of tests an average of 3,888 and in the other an average of 3,116 bacteria per cubic centimeter. The milk from the same cow drawn with aseptic precautions had in one set of experiments an average of 267 and in the other an average of 242 per cubic centimeter. In some samples the value of these aseptic precautions was even greater. Three tests gave respectively 25, 31, and 37 bacteria per cubic centimeter.

2. According to these experiments the aseptic methods used apparently increased the percentage of acid bacteria found in the milk; for, whereas in the ordinary milk the lactic bacteria

averaged 23 per cent., in the aseptic milk they averaged 42 per cent. This suggests, of course, that certain species of lactic bacteria are found in the milk ducts, and hence are not removed by our aseptic precautions. It is to be emphasized, however, that in none of these cases were the acid bacteria found the typical *Bact. lactis acidi*, but were always other species of less common and less well known dairy organisms.

COMPARISON OF ORDINARY MILK AND ASEPTIC MILK KEPT AT 70°.

1. The first point noticed is the very slight growth that takes place in the course of 12 hours in all samples. In the aseptic samples there was an average increase of three-fold; in the non-aseptic samples an average increase of ten-fold. This difference between the rapidity of increase in the ordinary and in the aseptic milk was found not only in the average, but also in practically every sample. In other words, in every test the bacteria *multiplied* more rapidly in the ordinary milk than in the aseptic milk. The interpretation of this fact is not clear, although a simple suggestion would seem to explain it without much difficulty. The aseptic milk contains mostly bacteria that were in the milk ducts, where they are of course accustomed to a warm temperature and, therefore, to conditions very different from those of the milk after it is drawn. Consequently the bacteria in milk containing only the bacteria from the udder contains a larger proportion of individuals unable to develop at a temperature of 70°. The non-aseptic milk, however, being contaminated largely with bacteria from external sources, contained more individuals capable of growing at a lower temperature, and therefore at the end of 12 hours showed a greater rate of increase.

2. The reduction of the number of bacteria from a few thousand in ordinary milk to a few hundred in aseptic milk has a very decided effect upon the number which may be expected at later periods of 12, 24, and 36 hours. The non-aseptic sample, which had at the outset an average of 3,888, showed at 12 hours 33,000, at 24 hours about 29,000,000, and at 36 hours 356,000,000. The aseptic sample, having an average in fresh milk of 267, showed at 12 hours 663, at 24 hours 1,176,000, and at 36 hours 55,000,000. This difference is more striking if the

tables are studied; for it is seen that the difference is not a difference of average simply, but a difference in practically every sample. The milk aseptically drawn, and containing small numbers at the start in every case, showed a very much smaller number of bacteria at the end of 12 hours, 24, and 36 hours than the milk drawn in the ordinary way. Here again the difference may be due in part to the fact that the aseptic milk contained a larger proportion of bacteria capable of growing only at high temperatures.

3. The effect of aseptic milking upon the development of acid in the milk was also noticeable. No increase in acid was found in the samples 24 hours old, but in 36 hours the ordinary milk showed an increase in acid from about .19 to .26, whereas the aseptic sample showed, even at 36 hours, no increase in acidity.

4. The time of curdling of the milk was similarly affected by the aseptic precautions. The ordinary milk curdled on an average in 79 hours; the aseptic milk in 113 hours.

5. Aseptic milking affects the percentage of lactic bacteria that is found in milk 36 hours old. In the non-aseptic samples there was an average of 86 per cent., and, leaving out one anomalous case, the 36-hour sample contained 100 per cent. of lactic bacteria. The aseptic samples, on the other hand, varied widely. There was an average of 51 per cent. at 36 hours, but this average, we notice from the table, is made up of numbers varying from 1 to 98 per cent. The aseptic precautions clearly, then, have an influence in checking the development of the ordinary lactic bacteria. This is a confirmation of the fact already noted in another place, that the milk freshly drawn from the cow does not contain the normal lactic bacteria. The aseptic milk, which excludes most of the external bacteria, therefore was likely to contain none or very few of these normal dairy forms at the outset. This explains readily enough the lower percentage of lactic organisms found at later hours in the aseptic milk.

6. The increase of bacteria in the aseptic sample in 36 hours was about 200,000-fold, in the ordinary milk about 100,000-fold. Whether this difference has any significance is doubtful.

COMPARISON OF ORDINARY AND ASEPTIC MILK KEPT AT 50°.

1. During the first 12 hours there was practically no increase of bacteria. Sometimes the numbers increased slightly, sometimes they remained constant, and in some cases they decreased in both the ordinary milk and the aseptic samples.

2. The effect of aseptic milking upon the numbers of bacteria found at later stages was even more striking than in milk retained at 70°. The ordinary milk, with an average of 3,116, at 12 hours showed 6,049, at 24 hours 22,170, and at 36 hours 101,000. The aseptic sample, having 242 at the start, showed at 12 hours only 363, at 24 hours 5,991, and at 36 hours 2,802. In other words, for 36 hours there was practically no increase of bacteria in the aseptic milk kept at 50°, although there was a decided increase in the ordinary milk during this time.

3. The average increase of bacteria at this temperature in 36 hours was ten-fold in the aseptic milk and thirty-fold in the non-aseptic milk. These results agree quite closely with those of milk preserved at 70° for 12 hours. In other words, milk kept at 50° is at the end of 36 hours in much the same condition as is milk kept at 70° for 12 hours.

4. Aseptic milking has a very striking effect upon the time of curdling. Ordinary milk kept at 50° curdled on an average in 226 hours, the aseptic milk in 400 hours. In one case the aseptic milk did not curdle for 1,300 hours, or 54 days.

GENERAL EFFECT OF A TEMPERATURE OF 50°.

1. The most striking results shown by these experiments is the effect of a temperature of 50° in checking bacteria growth. In 36 hours at 50° the average increase of bacteria is 10 and 30-fold in the aseptic and ordinary milk respectively; at 70° the increase is 200,000 and 100,000 fold. The significance of this fact in relation to the keeping quality of milk is very evident. In some experiments there was practically no growth of bacteria for 36 hours after the milk was drawn, if preserved at 50°.

2. The effect of the lower temperature upon curdling was equally striking, making it possible to keep milk without curdling for from 79 hours to 400 hours and in one case for 1,300 hours.

3. The effect of low temperature was to check the development of lactic bacteria, especially *Bact. lactis acidi*, and to produce a corresponding increase in the development of miscellaneous species. This is not brought out satisfactorily by these tables, except as indicated by the fact that the small percentage of lactic bacteria suggests a large percentage of miscellaneous forms. The great development of miscellaneous species at low temperatures will be treated more fully in a paper to be published later. A large amount of data upon the subject has been collected in connection with a different series of experiments. At this point it is necessary only to state the fact.

GENERAL RESULTS.

The general result of the investigations in this series of experiments is as follows: When the numbers of bacteria in fresh milk vary from 2,000 to 40,000 and are from both external and internal sources of contamination, no parallel can be drawn between the number of bacteria present at any later stage and the number present at the outset. This does not hold true when the numbers are still further reduced. By means of aseptic milking the numbers in this herd were reduced to about 300 per cubic centimeter, and this had a very striking result upon the numbers present in the milk at later stages, when the milk was preserved either at 50° or at 70°.

2. The bacteria which get into the milk from other sources than the milk ducts seem to grow more readily under ordinary conditions and ordinary temperatures than do the bacteria that find entrance from the milk ducts themselves.

QUALITATIVE ANALYSIS OF BACTERIA IN MARKET MILK.

BY H. W. CONN AND W. M. ESTEN.

Acknowledgment is hereby made to the Rockefeller Institute for Medical Research for financial aid which has made it possible to carry out the work of the following investigations.

In a paper previously reported (An. Rep. Storrs Exp. Sta., 1900) was described a method of study of the bacteria in milk, which gave from the direct reading of plate cultures not only the numbers of bacteria present in each sample, but, at least approximately, the number and percentage of the different species. Qualitative analysis of bacteria in milk has rarely been attempted, but the lessons which are to be obtained from such a study are extremely important in their bearing upon the general questions of milk bacteria related to both dairy and sanitary problems. The experiments reported in the present article are a continuation of those previously described.

The first series of experiments here described consisted of examinations of the milk brought to market by the milkmen of the city of Middletown. The purposes of the experiments may be briefly outlined as three.

1. To determine whether a qualitative analysis of market milk is possible, and whether such analysis is likely to give us useful data concerning the relation of bacteria to milk products.

2. To determine how great a variety of bacteria is shown by ordinary market milk.

3. To determine how great a variation there is in the species of bacteria present in the fresh milk of different dealers.

METHOD OF ANALYSIS.

The method adopted in this series of experiments is identical with that heretofore used and need not be described again here.

The culture medium employed was the litmus milk-sugar gelatin, whose method of preparation has already been given; and the method of using it was that described in the earlier paper.

The milk examined was obtained from each of the milkmen who furnish milk to Middletown, about twenty in all. This milk was always supposed to be fresh, since it was obtained from the milk cart in the early morning, taken immediately to the laboratory, and either plated at once or, if there was a delay of an hour or two, always cooled immediately with ice, so that little change could take place in the bacteria content before the plates were made. The milk was presumably only a very few hours old, since the farms are all close to the city, and the milk is delivered to the customer within one to three hours after leaving the farm. Some of this milk, however, was morning's milk, and some of it was the milk of the previous evening, so that the actual age varied from two hours to twelve hours or so.

As will be seen from tables below, the general character of the milk, so far as concerns bacteria, was exceptionally good. Middletown is a community of about 15,000 inhabitants, and the farms that produce the milk are located in the immediate vicinity of the city. As a rule the producer of the milk is also his own distributor, and the milk is put into the hands of customers in a much fresher condition than is possible in our larger cities. The highest number of bacteria found in any experiment was a trifle over 2,000,000, and this in only one case. In most analyses the number was far below this, being rarely as high as 100,000, numbers much lower than are found in the ordinary market milk of large cities. These experiments, therefore, while indicating the practical possibility of a qualitative analysis of milk bacteria in a small community, are as yet incomplete, since they do not include any study of the types of milk of the poorer character found in our larger cities. The experiments described in this series continued over a period of five months, beginning in February and extending into June. They therefore include some of the colder months of the winter as well as some of the warmer months of the summer.

The milk in all cases was treated as follows. A sample of the ordinary morning's supply was brought to the laboratory and

after very vigorous shaking was diluted with sterilized water. A proper differentiation requires that the milk should be diluted so that each plate shall have about 200 or 300 colonies. If the number is higher than this, the differentiation is unsatisfactory; if the number per plate is less, the results are somewhat unreliable, because the samples are too small. The first difficulty of the experiments is therefore to obtain a proper dilution. To insure a really satisfactory differentiation of species, it would be necessary to make plates from several grades of dilution for each sample of milk. This would vastly increase the labor, and after some preliminary experiments we found it most satisfactory to use for each experiment two grades of dilution. In all of the experiments described we used dilutions of 100 and 600, thus giving a double chance of obtaining satisfactory plates for study. Sometimes one and sometimes the other of these dilutions was the more useful. In a few cases where the number of bacteria proved to be very large, the dilution of 600 diameters was insufficient for proper differentiation; and if this method were to be adopted in larger cities, where the numbers are commonly higher, it would be necessary to make the dilution higher than 600. But with the exception of two or three experiments, the dilution of 600 has been quite sufficient for our market milk, and in many cases the dilution of 100 was more satisfactory.

Before describing the results in detail it is necessary to describe the types of bacteria found in the normal milk of this vicinity. The number of species in the milk is of course quite large, but of the large number of species found a few seem to be present almost universally, while the others are present in a small number of the samples of milk, and when present are as a rule only few in number. We therefore may readily divide the milk bacteria which we have found into the normal forms and the unusual forms, with of course no sharp line separating the two. The unusual forms of bacteria are, for the present purposes, of little significance, although it may be that they will prove in the end to be of more significance than the normal types. Our experiments, however, were planned to determine the proportions of the normal bacteria in milk in different samples.

GROUPS OF MILK BACTERIA.

A long study of the ordinary milk bacteria of this locality has shown us that they may quite satisfactorily be divided into several groups. This grouping has been selected because each of the groups is capable of tolerably sharp differentiation upon the litmus gelatin plates. Although the basis of the arrangement is their action upon litmus gelatin, it is found that the groups selected have each a special relation to milk and are thus significant in the consideration of dairy problems.

The groups into which we have divided the bacteria are as follows:

Group I. *Bact. lactis acidi* group. This is the most widely distributed of all lactic bacteria and has been fully described in other places. It appears upon our plates as a small opaque colony, growing under the surface only, and with its periphery marked by minute spines showing with a 1 inch objective. The colony is red and is surrounded by a red halo. We have isolated large numbers of these colonies from the plates and carefully studied them by culture methods. They all prove to be *B. lactis acidi*, although showing variation in their power of curdling milk, some curdling it rapidly, others slowly, and others not at all (See paper by Esten in Rep. of this Station, 1896). They are usually very easily differentiated upon our plates and are few in numbers in fresh milk but abundant in old milk—No. 206 of our classified list.

Group II. *Bact. lactis acidi II.* group. This is represented apparently by a single species. It is very closely related to Group I. and has much the same action upon the milk. It differs from Group I. chiefly in its colony on litmus gelatin, which is very small, usually invisible to the naked eye, and quite transparent. It is more feebly acid than the colony of Group I. and lacks the characteristic spines. It is rarely found in fresh milk, but is common in old milk, especially in some samples kept at high temperatures. The group seems to be sharply differentiated from others on the plates, and the many colonies isolated all prove to be the same species, No. 202 of our classified list.

Group III. *Bact. lactis aerogenes* group. The typical species of this group is *B. lactis aerogenes* (Escherich), which is a

non-motile rod, producing lactic acid, but not readily curdling milk, and fermenting milk sugar with the production of gas. Upon our plates it produces a colony which is of good size, $1/3$ mm., growing under the surface and on the surface and surrounded by an intensely red ring. This acid ring is much more intense than that of either Group I. or Group II., in spite of the fact that the species does not commonly curdle milk. Frequently the colony has a gas bubble beneath it, and it sometimes grows vertically up from the surface of the gelatin into a mound, which may be higher than broad. They are commonly the most striking colonies on the plate. One curious feature concerning the colonies is that although at first they are very acid and turn the gelatin in their vicinity a bright red, after a number of days the red color disappears, and the litmus turns blue again. A plate inoculated with pure cultures of this organism becomes in two days very red; but after about a week some colonies become blue, and in a few days the whole plate is strongly blue again. To what this change in reaction is due we have not yet determined.

This group, unlike the first two, includes several different species. We have isolated and studied many colonies of the character described, and find that there are at least four different types. Besides the typical *Bact. aerogenes*, No. 208 of our list, there is a species similar in all respects except that it fails to ferment milk sugar with the production of gas—No. 223 of our list. This is about equally abundant with No. 208. Some of the colonies prove to be *B. coli communis*, differing from the first two species in being motile. In our studies these have not been so numerous as the first two. Some colonies prove to be cocci instead of rods, but in other respects apparently identical with *Bact. aerogenes*—No. 224 of our list. Other colonies agree with this last except in failing to ferment milk sugar—No. 168 of our list. In a few cases we have found that these colonies prove to be different from any of the others. This group is therefore a somewhat miscellaneous one, which further study may enable us to differentiate; but the colonies produced by all the species are so nearly alike that at present we are unable to differentiate them on our plates, and are therefore forced to include them in a single group. Practically this Group III. includes nearly all of the aerobic lactic bacteria,

while Groups I. and II. include the anaerobic or facultative anaerobic bacteria, that grow very scantily upon the surfaces of media.

Frequently acid colonies are found that seem to belong to none of these three groups. This is due sometimes to species different from any of those above mentioned; but more commonly it is attributable to the fact that some colonies do not show their typical characters. This is especially the case when, because of liquefiers, the plates must be studied before they are old enough. This lack of differentiation of course introduces an error in the results. In our tables these colonies are included in the column headed acid, species undetermined. Most of the bacteria there listed would be properly placed in Groups I., II., or III., if a perfect differentiation had been possible, although some probably belong to Group V., and some perhaps belong elsewhere.

Group IV. *Streptococcus* group. This group is less sharply differentiated and is in general of a neutral character as relates to milk. It includes colonies with no particular characteristic. They are never acid and rarely alkaline in reaction; they are commonly rather opaque, small, round colonies while under the surface of the gelatin, but may spread over the surface to form a white colony a millimeter in diameter. They are separated from others in the study of the gelatin plates by lacking any distinctive characteristics; and it is to be suspected, therefore, that they comprise a number of species. We have isolated and studied a large number of the colonies tabulated in this column from many different samples of milk, and have thus far found them to consist of four species of milk bacteria. Of these the majority are streptococci, from which we have named the group, No. 229. Some of them are bacilli agreeing with the streptococci in most of their characteristics—No. 194. A third species is a rare fluorescent, bacillus No. 90, while Nos. 205 and 224 of our list are occasionally grouped here. Although this group is, then, a miscellaneous collection, the colonies are all neutral in their action. None of them produces any visible effect on milk; none of them produces enzymes; and none of them produces any signs of putrefaction. So far as we have been able to determine, they are of no significance in the milk. Experiments not here reported have shown us that they come

from the milk ducts in many cases, are most abundant in fresh milk, but largely disappear in older milk as the lactic bacteria become abundant. Their lack of action upon milk has led us to group them together without attempting further differentiation.

Group V. *Yellow coccus* group. We have found almost universally in milk of this region coccus forms that produce yellow colonies. They grow both below and on the surface, and are sometimes a faint and sometimes a very brilliant yellow. There appears to be two types, one producing an acid colony, No. 231, though it fails to curdle milk, and the other developing a colony with no trace of acid. These two types we have placed together in one column in our tables, although they are readily differentiated upon our plates. Some of the cultures prove to be a species of Sarcina (Sarcina lutea), while others are typical Micrococci, the cocci being almost always grouped in fours, indicating division in two planes only. Their action upon milk is very slight.

Group VI. Rapid liquefying group. These are characterized by a gelatin colony liquefying with great rapidity, so that a single colony will liquefy a whole plate in two to three days. There are three or four species here included, but we have as yet made no attempt to differentiate them. One of the common species is *B. fluorescens liquefaciens*, and another is *B. subtilis*. They are distinctly putrefactive species, and their presence in milk in abundance will undoubtedly render it unwholesome. They are never very numerous in milk, and the few present in fresh milk are usually overcome by the lactic bacteria, so that they are not found in older samples of milk.

This group of bacteria proves to be the most serious obstacle to a successful differential analysis of milk. The spreading of the liquefying area rapidly involves the whole plate, and if these colonies are numerous, the gelatin is all liquefied before it is in condition for study. Even three or four such colonies may ruin a plate, and if the sample of milk contains members of this group, the analysis is sure to be difficult, uncertain, and sometimes impossible. Various attempts have been made to meet the difficulty. The use of agar instead of gelatin is not satisfactory, since these bacteria are likely to spread over the whole surface and produce about as much trouble as in gelatin;

and moreover the differentiation of colonies is quite unsatisfactory upon agar plates. After trying various devices, we have finally adopted one that is in a measure successful. If we examine our plates at the end of one or two days, the rapid liquefiers are already evident and may be commonly detected at a glance. If they are numerous, the plate is hopeless; but if there is only a small number of them upon the plate, we frequently save it by dropping into the center of the colony a single drop of twenty per cent. sulphuric acid. When properly used, this stops the growth of the bacteria and checks the liquefaction. It is necessary to use a drop of the acid proportional to the size of the colony. If too much is added, the acid diffuses itself through the litmus and turns it red for some distance around the colony, making it impossible to study the colonies of other bacteria within this particular area. If the drop is too small, it does not stop the liquefaction. If the drop is of the proper size, the acid does not diffuse itself through the gelatin, stops the liquefaction quickly, and does not injure the plate for further study. The use of sulphuric acid in this way makes it possible to save for study many gelatin plates that would otherwise be totally ruined by the rapid liquefiers. This remedy for liquefaction is not possible if the rapid liquefiers are very numerous, but we have found, nevertheless, that it is extremely useful. In many cases it has made it possible to keep for many days, and to obtain satisfactory results from their study, plates which would otherwise be ruined by the liquefiers before old enough for a satisfactory differentiation.

Group VII. Slow liquefying type. These bacteria liquefy the gelatin very slowly, and frequently even after a week's growth produce only small liquefying pits. Their presence in a plate, unless they are very numerous, does not interfere with the preservation and subsequent study of the colonies. They are commonly more abundant in fresh milk than is Group V., but are also later replaced by the acid bacteria. In the present paper we shall not attempt to differentiate this group into species, although it can be done easily. A considerable number of species are included in the group, most of which can be distinguished easily by their colonies upon plates. All, of course, produce enzymes, and most of them are more or less putrefactive in their action. We believe they are of much significance

in milk. Their presence in large numbers probably always indicates excessive filth; and we always regard with suspicion samples of milk containing numerous liquefiers. The reasons for this suspicion will not be given at this point, beyond the general fact that liquefiers do not come from the milk ducts, nor are they likely to be abundant in milk pails. Consequently their presence means external contamination from manure or other dirt.

In the experiments given below it was not always feasible to separate Groups V. and VI., and in some tables all liquefiers are given in one column. In such experiments it will be understood that most of the liquefiers were slow growers.

The next three groups consist of a single species each. None of them is apparently of much significance, and none of them has any effect on milk. Descriptions of the organisms will be published later.

Group VIII. This is number 222 of our list, and is recognized from its producing a *pale*, *thin* colony upon litmus gelatin. The colony is slightly yellowish, grows under the surface, and is transparent. It proves to be difficult to cultivate and has no action on milk. It is found on nearly all samples of milk, and sometimes in large numbers. It disappears as the milk becomes older.

Group IX. This is number 227 of our list, recognized by producing a *red-brown*, opaque colony.

Group X. This is number 228 of our list, recognized from its *halo colony*. This has a dense center surrounded by a clear ring, growing below the surface. It proves to be a very slow liquefying colony, growing slowly.

Group XI. Miscellaneous. In every sample of milk there is quite sure to be a small number of species of bacteria peculiar to the sample but not found in other samples. Such species are usually easy to distinguish from the more common species. In some samples a single such species is found; in others four or five. They are always few in numbers, usually less than 1 per cent. Occasionally, however, one of these species may constitute 10 per cent. of the bacteria in a sample of fresh milk, indicating of course that there was in this case some

peculiar source of contamination. In the following tables it did not seem feasible to tabulate each of these accidental species separately, and they are therefore grouped together in the column Miscellaneous. This group, therefore, includes easily differentiated bacteria, sometimes a single species and sometimes several. In experiment with No. 8 in June as many as eight species are here included. The work of classifying all these species has not yet been completed.

Group XII. Undetermined. This column is simply the expression of the incompleteness of the differentiation. After counting all the colonies which were capable of recognition as belonging to the various groups, the numbers of the different recognizable species were added together and subtracted from the total number of colonies, the difference giving the number of undetermined. This column indicates therefore the number of colonies that were not characteristic enough to determine accurately. Nearly all of them would be placed in Groups I., II., and IV., if the differentiation had been complete. The larger the proportion of liquefiers, as a rule, the larger this column of undetermined.

REPORTS OF ANALYSES.

From the analyses of milk from the milkmen of Middletown we have selected 27 experiments, the results of which are given in the following table. In this table the number of bacteria per cubic centimeter is given first, and below is the percentage of each group detected. The numbers represent the average of all plates made, half of which contained milk diluted 100 times and half 600 times; and since the dilution of 600 always gave higher numbers than that of 100 times, the figures given are smaller than the actual numbers.

COMMENTS ON THE FOLLOWING TABLE.

No. 3. March. Good milk, doubtless fresh.

No. 4. March. Good milk, doubtless fresh.

No. 5. March. Good milk, doubtless fresh.

No. 6. March. Numbers rather high, but percentage of different species normal. Probably fresh, but badly contaminated with bacteria.

No. 7. February. Numbers high, and percentage of Group I. too high for fresh milk.

No. 7. June. Not fresh, or too warm.

No. 8. February. Milk undoubtedly old. Percentage of Group I. is very high.

No. 8. April. Probably not strictly fresh. Compare with same dealer above.

No. 8. June. Doubtless fresh. 17 distinguishable species of bacteria in this sample.

No. 9a. April. Results unreliable because of the interference of liquefiers. The milk was doubtless badly contaminated and was not very fresh.

No. 9b. April. Contained large numbers of a species not present in milk from the same source two days before, given in the last column.

No. 10. April. Excellent quality.

No. 10. June. Excellent quality. Compare with milk of same dealer above.

No. 11. April. Probably not fresh, since the percentage of Group I. is too high.

No. 11. May. Doubtless an old lot of milk, as shown by numbers and percentage of Group I.

No. 12. May. Cows fed upon silage and grass. Large numbers of liquefiers rendered the determination of acid columns uncertain.

No. 14. June. Milk is old, as proved especially by percentage of Group II.

No. 16. June. Not fresh, or too warm, as shown by Groups I. and II.

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TABLE 12.—*Bacteria found in market milk samples taken in Middletown, 1903.*

Per cent. of the total in bold faced type.

Dealer.	Month.	Total.	B. Lactis Acidi.	B. Lactis Acidi II.	B. Aerogenes.	Streptococci B. etc.	Sarcina.	Rapid Liquefiers.	Slow Liquefiers.	No. 222.	No. 227.	No. 228.	Miscellaneous.	Acid Species Undetermined.	Undetermined.	Small Lobed.
No. 1	February, -	48,000	2,250	—	—	9,400	940	325	4,250	8,500	425	150	5,300	5,500	10,960	—
		100	**4.6**	—	—	**19.5**	**2.**	**.7**	**8.8**	**17.7**	**.8**	**.3**	**11.**	**11.4**	**23.2**	—
No. 1	April, -	82,600	7,000	—	—	29,800	—	—	10,400	11,800	9,600	—	200	9,600	4,200	—
		100	**8.5**	—	—	**36.1**	—	—	**12.6**	**14.2**	**11.6**	—	**.3**	**11.6**	**5.1**	—
No. 1	May, -	122,600	7,600	—	—	50,000	3,200	800	13,800	3,400	600	400	1,000	8,400	33,400	—
		100	**6.2**	—	—	**40.8**	**2.6**	**.7**	**11.3**	**2.8**	**.5**	**.3**	**.8**	**6.8**	**27.2**	—
No. 2	March, -	108,000	32,500	—	25	26,000	850	700	7,500	—	6,900	—	—	20,000	13,525	—
		100	**30.1**	—	?	**24**	**.8**	**.7**	**6.9**	—	**6.4**	—	—	**18.5**	**12.6**	—
No. 2	June, -	267,300	61,500	86,400	—	9,300	—	300	108,900	—	—	900	—	—	—	—
		100	**23**	**32.3**	—	**3.5**	—	**.1**	**40.8**	—	—	**.3**	—	—	—	—
No. 3	March, -	9,000	950	—	—	3,150	—	1,050	1,300	1,000	—	—	—	1,550	—	—
		100	**10.5**	—	—	**35**	—	**11.7**	**14.4**	**11.1**	—	—	—	**17.3**	—	—
No. 4	March, -	14,500	4,025	—	—	5,400	700	—	1,350	1,700	25	—	—	150	1,150	—
		100	**27.8**	—	—	**37.2**	**4.8**	—	**9.5**	**11.6**	**.2**	—	—	**1.**	**7.9**	—
No. 5	March, -	8,100	300	—	—	2,425	650	—	3,500	550	50	—	—	—	615	—
		100	**3.7**	—	—	**30**	**8**	—	**43.3**	**6.8**	**.6**	—	—	—	**7.6**	—
No. 6	March, -	100,000	5,600	—	50	59,000	1,350	950	3,950	12,000	1,300	—	2,850	1,500	11,450	—
		100	**5.6**	—	?	**59**	**1.4**	**.9**	**4**	**12**	**1.3**	—	**2.8**	**1.5**	**11.5**	—
No. 7	February, -	157,500	40,000	19,000	—	45,500	2,250	3,650	4,600	13,600	1,100	—	1,000	—	26,800	—
		100	**25.4**	**12.1**	—	**28.9**	**1.4**	**2.3**	**2.9**	**8.6**	**.7**	—	**.6**	—	**17.1**	—
No. 7	June, -	514,800	246,000	236,000	1,200	16,600	4,100	—	8,800	—	300	—	—	—	1,800	—
		100	**47.7**	**45.8**	**.2**	**3.2**	**.8**	—	**1.7**	—	**.1**	—	—	—	**.4**	—
No. 8	February, -	737,000	647,000	21,500	—	21,500	3,250	—	—	21,900	—	2,000	—	—	19,810	—
		100	**87.7**	**2.9**	—	**2.9**	**.5**	—	—	**2.9**	—	**.3**	—	—	**2.8**	—
No. 8	April, -	96,500	19,000	—	200	34,000	700	—	15,000	12,500	350	—	500	6,500	7,750	—
		100	**19.8**	—	**.2**	**35.2**	**.7**	—	**15.5**	**12.9**	**.4**	—	**.5**	**6.8**	**8**	—

TABLE 12.—*Continued.*

Dealer.	Month.	Total.	B. Lactis Acidi.	B. Lactis Acidi II.	B. Aerogenes.	Streptococci B. etc.	Sarcina.	Rapid Liquefiers.	Slow Liquefiers.	No. 222.	No. 227.	No. 228.	Miscellaneous.	Acid Species Undetermined.	Undetermined.	Small Lobed.
No. 8	June, -	54,200	3,900	—	150	12,750	3,600	300	1,770	—	2,600	300	5,080	1,050	22,700	—
		100	7.2	—	.3	23.5	6.6	.6	3.3	—	4.8	.6	9.3	1.9	41.9	—
No. 9a	April, -	545,000	9,600	44,800	—	160,000	1,400	—	106,600	12,000	200	—	—	52,400	158,000	—
		100	1.8	8.2	—	29.2	.3	—	19.6	2.2	?	—	—	9.7	29	—
No. 9b	April, -	132,000	5,350	—	—	16,000	800	—	3,000	5,000	250	—	—	59,000	8,100	34,500
		100	4	—	—	12.1	.6	—	2.3	3.9	.2	—	—	44.7	6.1	26.1
No. 10	April, -	11,000	1,150	—	—	6,000	600	—	1,025	1,050	—	—	—	675	500	—
		100	10.5	—	—	54.6	5.4	—	9.3	9.5	—	—	—	6.1	4.6	—
No. 10	June, -	30,000	1,750	100	—	11,150	3,900	200	5,250	450	—	—	700	1,150	5,550	—
		100	5.8	.3	—	37.2	13	.7	17.5	1.5	—	—	2.3	3.8	17.9	—
No. 11	April, -	191,900	40,600	—	—	64,800	4,500	—	27,500	9,200	1,100	4,500	—	12,800	26,900	—
		100	21.2	—	—	33.8	2.4	—	14.4	4.8	.5	2.3	—	6.6	14	—
No. 11	May, -	2,973,800	2,729,000	179,600	—	20,000	—	—	45,000	—	—	—	—	—	200	—
		100	91.8	6.	—	.7	—	—	1.5	—	—	—	—	—	?	—
No. 12	April, -	81,500	14,000	—	300	34,000	500	—	3,900	9,900	550	100	—	8,100	10,150	—
		100	17.2	—	.4	41.7	.6	—	4.8	12.1	.7	.1	—	9.9	12.5	—
No. 12	May, -	103,000	800	—	200	40,000	4,000	800	28,600	3,000	1,800	—	4,400	3,800	15,600	—
		100	.8	—	.2	38.9	3.9	.8	27.8	2.9	1.7	—	4.2	3.7	15.1	—
No. 12	June, -	40,700	1,350	400	—	19,500	700	1,550	5,250	350	—	300	—	1,600	9,700	—
		100	3.3	1.	—	47.9	1.7	3.8	12.9	.9	—	.7	—	4.	23.8	—
No. 13	April, -	30,600	900	—	—	7,800	1,150	—	11,300	3,000	1,150	750	300	2,600	1,650	—
		100	2.9	—	—	25.5	3.7	—	36.9	10.	3.7	2.4	1	8.5	5.4	—
No. 14	June, -	348,350	36,300	275,000	—	16,900	7,200	350	9,500	—	—	—	3,100	—	—	—
		100	10.4	79.	—	4.8	2.1	.1	2.7	—	—	—	.9	—	—	—
No. 15	June, -	18,400	1,850	—	—	3,550	250	—	6,500	350	150	—	—	4,100	1,650	—
		100	10.	—	—	19.4	1.3	—	35.3	1.9	.8	—	—	22.3	9.	—
No. 16	June, -	367,000	155,000	43,000	—	3,500	1,100	—	75,000	—	—	—	—	—	89,400	—
		100	42.2	11.7	—	1.	.3	—	20.4	—	—	—	—	—	24.4	—

The study of the preceding table shows the following more important facts.

1. There is a wide variation in the numbers of bacteria, the number varying from 8,000 to 2,900,000. Considering the fact that the milk delivered here is all supposed to be only 2 to 12 hours old, this variation in numbers indicates a wide variation in the conditions under which the milk is produced.

2. With the increase of numbers of bacteria in the milk there is a more or less constant, but by no means regular, increase in the percentage of acid bacteria. This may be perhaps more satisfactorily shown if these figures be given in a table by themselves. In the following table are given in the first

TABLE 13.

Showing increase of percentage of acid bacteria with increase in total numbers of bacteria.

Dealer.	Date.	Total Bacteria.	Percentage of Groups I. and II.	Percentage of Liquefying Bacteria.
No. 5,	March, - - - - - -	8,100	3.7	43.3
No. 3,	March, - - - - - -	9,000	10.5	26.1
No. 10,	April, - - - - - -	11,000	10.5	9.3
No. 4,	March, - - - - - -	14,500	27.8	9.5
No. 15,	June, - - - - - -	18,400	10.0	35.3
No. 10,	June, - - - - - -	30,000	6.1	18.2
No. 13,	April, - - - - - -	30,600	2.9	36.9
No. 12,	June, - - - - - -	40,700	4.3	16.7
No. 1,	February, - - - - - -	48,000	4.6	9.5
No. 8,	June, - - - - - -	54,200	7.2	3.9
No. 12,	April, - - - - - -	81,500	17.2	4.8
No. 1,	April, - - - - - -	82,600	8.5	12.6
No. 8,	April, - - - - - -	96,500	19.8	15.5
No. 6,	March, - - - - - -	100,000	5.6	2.3
No. 12,	May, - - - - - -	103,000	0.8	28.6
No. 2,	March, - - - - - -	108,000	30.1	7.6
No. 1,	May, - - - - - -	122,600	6.2	12.0
No. 9b,	April, - - - - - -	132,000	4.0	2.3
No. 7,	February, - - - - - -	157,500	37.5	3.7
No. 11,	April, - - - - - -	191,900	21.2	14.4
No. 2,	June, - - - - - -	267,300	55.3	40.9
No. 14,	June, - - - - - -	348,350	89.4	2.8
No. 16,	June, - - - - - -	367,000	53.9	20.4
No. 7,	June, - - - - - -	514,800	93.5	1.7
No. 9a,	April, - - - - - -	545,000	10.0	19.6
No. 8,	February, - - - - - -	737,000	90.6	0.0
No. 11.	May, - - - - - -	2,973,800	97.8	1.5

column the total numbers of bacteria in different samples tested, arranged in the order of their size. In the second column is given the percentage of acid bacteria in each sample, only Groups I. and II. being included, and in the third column appears the percentage of liquefiers.

A glance through the figures will show that although there is no regular increase in the percentage of acid organisms as the numbers rise, a general increase is very clear. The larger per cents. of acid organisms are found only in the samples where the numbers of bacteria have become somewhat large. No sample which shows more than 50 per cent. of the acid organisms contained less than 250,000 to 300,000 bacteria, and the only samples where the acid organisms were as high as 90 per cent. were three in each of which the total number of bacteria was in excess of 500,000. On the other hand, in all of the samples where the percentage of lactic organisms is small, below 10 per cent., the number of bacteria is correspondingly small, in few cases rising to more than 50,000 per cubic centimeter. This conclusion is quite in accordance with the facts brought out in a previous paper, that with increase in the age of the milk there is, along with the actual increase in numbers of bacteria, a very noticeable increase in the percentage of lactic bacteria. The conclusion is that a large per cent. of acids must indicate, in all probability, that the milk is somewhat old or has been kept under moderately warm conditions.

It must, however, be noticed that this parallel does not always hold, and that there are some samples in which the percentage of acids and the total numbers do not increase together. In experiment No. 18 the total number of bacteria was quite high, 100,000, while the acid organisms in this case were very few in number, only .8 per cent. In this sample the cows were fed with a considerable quantity of grass and ensilage, and probably this fact somewhat modified the conditions; while the abundance of liquefiers rendered the detection of acid colonies difficult. Probably some of Group IV. were really lactic bacteria. The same results can be seen from experiments Nos. 10 and 11, in which tolerably high total numbers of bacteria show only moderately low percentages of lactic organisms.

As a converse to the last conclusion, it will be noticed from Table 13 that milk containing small total numbers of bacteria

contained in all cases small per cents. of acid organisms. There are no striking exceptions to this rule in the samples given, although in experiment No. 4, showing a total number of 14,500, there was 27.8 per cent. of acid organisms. This is the only exception we have found to the rule that small total numbers of bacteria mean small percentages of lactic organisms.

From these results we draw the following conclusions:

1. In our market milk the presence of a large percentage of acid organisms indicates that the milk is not fresh or has been kept under too warm conditions.

2. If the milk contains a large total number of bacteria, the inference is that the great majority of these will be the harmless and even useful lactic organisms. This inference, however, is not always strictly accurate and could never be made with certainty without an actual qualitative test.

3. The next conclusion from our table is that when the number of bacteria is large, the number of varieties is small. This has been brought out in nearly every experiment, although again with no absolute regularity. Large numbers of bacteria always indicate a considerable percentage of lactic organisms, and the lactic organisms have a tendency to check the development of the other species of bacteria present, if not to actually destroy them. Hence, the older the milk, the less significant are the miscellaneous bacteria present. The converse of this proposition is usually, though not always, true; namely, that samples of milk containing small total numbers of bacteria contain a large number of varieties. This conclusion, as would be expected, cannot always be relied upon, because some samples of milk may be obtained under such favorable conditions that the total number of bacteria and also the number of varieties are both small; but for a miscellaneous lot of milk samples this conclusion holds true. It must be pointed out that this conclusion is to be explained in a measure by the fact that the plates which were made of milk containing small numbers of bacteria had fewer individual colonies, and under these circumstances the differentiation of species is much more easy and accurate. It is a simpler matter to obtain the varieties of bacteria from samples of milk that contain small total numbers than from samples containing large total numbers.

But, making due allowance for this possibility of error, it is manifest to us that the presence of small numbers of bacteria indicates, as a rule, the presence of a large number of varieties.

4. The liquefying bacteria in general vary inversely with the total numbers. The liquefying bacteria, many of which produce putrefactive decomposition, are a group of organisms very undesirable in milk. They tend to produce the putrefaction of milk, and when they are present in large numbers must render the milk unwholesome. From the preceding table, the relation of the percentages of liquefiers to the total numbers of bacteria is indicated. It will be seen that, although there are some irregularities, nevertheless the tendency is exactly the reverse of that of the lactic organisms. The percentage of the liquefiers is commonly largest in the samples of milk containing the smallest number of bacteria, and smallest in the samples of milk containing the largest number of bacteria. In the older samples, where the lactic organisms had become quite abundant, the liquefying forms sometimes almost disappeared, and always became relatively very few in numbers. This fact was shown better in the previous paper, where still older samples of milk were analyzed. In the fresh milk, where the number of bacteria was small, the percentage of liquefiers shows the widest variation, as would be expected from the different conditions of contamination; but if liquefiers are present in fresh milk, the percentage is likely to be high. In general, then, the percentage of liquefiers is the reverse of the percentage of lactic organisms. In samples of fresh milk they are likely to be abundant, while in the samples of older milk this group of organisms has a general, though not universal, tendency to disappear.

5. The liquefying bacteria vary with the seasons of the year. The experiments described ran through a series of months beginning with February and extending until about the first of July. They extended through the period of winter feeding into the period of spring feeding, and up to the time when there appears in the milk and in the butter the so-called June-grass flavor. From the table it will be found that there is a general increase in numbers of bacteria in the spring months, the numbers found in May and June being, on the whole, considerably

higher than those found in the earlier season. It will be found, moreover, that the liquefiers become relatively more abundant after the cows have left off the winter feeding and have been turned into the fields. Taking individual experiments from the above tables, this is not very evident, because individual experiments in the winter may show as high percentages of liquefiers as individual experiments in the later months. But if the average of liquefiers in all of the samples previous to the time when the cows were turned into pasture be compared with the average percentage of liquefiers in the samples of milk taken from the cows after they had begun to feed upon green pasturage, it will be found that there is a very noticeable difference. The average percentage of liquefiers is greater in the grass fed cows than it is in the barn fed cows, the actual numbers being as follows. The average percentage of liquefiers in fifteen experiments with cows stall fed is 12.6. The average percentage of liquefiers in animals that had been feeding in the pastures is 16.5.

This conclusion seems to us to be at least suggestive. The appearance of the grass flavor in June milk and June butter has always been a question to which no satisfactory answer has been made. It has been pretty generally attributed to the difference in the nature of the food, although bacteriologists have been, at least occasionally, inclined to attribute it to the kinds of bacteria that are present in the milk under the different conditions. As indicated by our experiments, the acid organisms found in the winter and in the summer, and therefore in milk from stall fed and grass fed cows, are essentially identical. At least we have as yet been unable to make out any difference either in the species, in the numbers, or in the rapidity of growth of the lactic bacteria in the different seasons of the year. Moreover, as has been pointed out in a previous publication, the lactic organisms fail to give the peculiar flavors which are characteristic of certain types of butter; and certainly the lactic organisms do not produce, when used for artificial inoculation into cream, the high flavors which characterize the so-called June butter. It has been our contention in previous writings that these flavors are probably the result not of lactic organisms but of other species growing along with them, and

the suggestion was made that it is the organisms which produce albuminoid decomposition which are responsible for at least some of these flavors in milk products. It is therefore to us a suggestive fact to find that when the cows are fed upon grass there begins an increase in these particular types of bacteria, and that the milk develops the so-called grass flavor. The general conclusion seems to be warranted that this increase in the percentage of liquefiers is one of the factors which account for the development of the grass flavors that appear in the early summer months.

6. The different samples of milk showed the widest differences in the number of varieties that were present. In some cases the number of kinds of bacteria was only four or five, these samples being the ones where the percentage of lactic organisms was high. In other cases, however, the varieties were very great. In the sample No. 27, a test made in May, although the number of bacteria was about 50,000, there were no less than 17 easily recognized species of bacteria distinguished on our plates, and these 17 would have been increased somewhat if it had been possible to differentiate completely all of the species. Between these two extremes the different samples showed great variations in the number of kinds of bacteria present.

MODIFICATIONS OF METHODS OF STUDY.

Our work up to this point was done with the culture media described in our previous report. By the time this series of experiments was finished certain imperfections in the culture media were recognized, and there appeared several points at which the method possibly might be improved. The chief points where improvement seemed to be needed were two. 1. Sterilization of the gelatin culture media always decolorized litmus which it contained, and although the solution after subsequent standing again acquired a blue color, the results were somewhat irregular. Moreover, it was not possible to obtain the same depths of blue color in different lots of gelatin. 2. Certain facts led us to suspect that the culture media made of peptone, etc., did not furnish the best condition for the growth and differentiation of milk bacteria. It would seem

that the typical milk bacteria would be more likely to develop vigorously in solutions containing milk than in a medium made up as the ordinary culture medium is. To determine, therefore, whether it was not possible to improve the methods of study, a long series of experiments was begun to test a number of culture media under a variety of conditions.

MODIFICATION OF CULTURE MEDIA.

After some trials we finally adopted a new method of mixing litmus with the gelatin, which has done away completely with the irregularities of the earlier medium. In our earlier method we mixed the litmus solution with the peptone gelatin, etc., when the medium was prepared, giving a blue mixture difficult to neutralize and lacking in uniformity. We now keep the litmus solution totally separate from the gelatin until the time of using.

The details of our method of preparing the litmus solution are as follows:

Fifty grams of dry litmus cubes are mixed with 300 cubic centimeters of water. This mixture is allowed to steep for a few hours at about 70°C., or soaked for 24 hours at the ordinary room temperature, for the purpose of dissolving the active material from the litmus. The solution is then filtered, giving a deep blue solution. This material is always alkaline to litmus, as shown by its deep blue color, but it is found to be acid to the phenol-phthalein test. In order to use it, the litmus solution must be brought to the same grade of alkalinity that is desired for the final culture media (1.5 per cent. acid to phenol-phthalein). To do this, it is necessary first to determine the exact reaction of the litmus solution. Five cubic centimeters of this solution is placed in an evaporating dish and diluted with 45 cubic centimeters of water. This is titrated with $\frac{1}{10}$ normal hydrochloric acid until the *litmus* neutral point is reached, the point being recognized by the turning of the color into a faint red. The reading upon the burette will of course show how much $\frac{1}{10}$ HCl is needed to bring 5 cubic centimeters of the litmus solution to the litmus neutral point. An average of three tests is needed, and the amount of normal HCl necessary to bring the whole litmus solution to the litmus neutral point is determined by calculation. This amount of HCl is added to the solution.

The solution thus neutralized is too strongly acid for bacteria growth. The grade of acidity which we have chosen for our experiments (see below) is 1.5 per cent. acid to phenol-phthalein, and the litmus neutral point of the litmus solution is found to be about 2.5 per cent.; *i. e.*, it requires 25 cubic centimeters of normal NaOH per liter to bring it to the neutral point of phenol-phthalein. In order to bring the litmus to the grade of acidity desired, namely, 1.5 per cent., there evidently must be added to the neutral litmus solution 10 cubic centimeters NaOH for each liter, thus bringing the acidity from 2.5 per cent. down to 1.5 per cent. This correction is therefore made. It is evident that the litmus solution thus obtained may be mixed with a culture media having the same degree of acidity without any change in acidity of the mixture. After bringing the litmus solution to the desired acidity, the whole is placed in a sterilized flask plugged with cotton, and sterilized with steam upon three successive days in the same manner as ordinary liquid media. Under these circumstances the sterilization does not decolorize the litmus solution, which retains its deep blue color through the successive sterilizations. This litmus solution is then set aside to be mixed with the culture media at the time of using. It may be kept indefinitely, care being taken to sterilize it after it has been opened for any purpose.

The litmus obtained in commerce has a varying strength and therefore cannot be relied upon always to give the same results where treated in the same way. Our method of meeting this difficulty is to buy litmus in large quantities and then by testing a sample of the material to determine the amount of the litmus solution that is needed to give the desired depth of blue in the gelatin plates. Having once determined this quantity, the solutions of this lot of litmus may be used in the same proportions until it is exhausted. A new lot of litmus requires a new test and a new proportion. By acting according to this simple means it is always possible to have the desired amount of blue color in the litmus. We have found usually that 2 cubic centimeters of this litmus solution are required for 8 cubic centimeters of culture medium.

EXPERIMENTS WITH DIFFERENT CULTURE MEDIA.

To determine the best culture medium required a longer series of experiments. Three different culture media were used in comparative tests, made as follows:

Milk whey culture media.—To about two liters of milk there is added enough rennet to curdle the milk in about half an hour. After a thorough curdling the curd is cut to pieces with a knife to allow the whey to exude, and the whole is then strained through a cheese cloth. The whey thus pressed from the curd is placed in a flask and sterilized in an autoclav for forty minutes at a pressure of 5 pounds. This sterilization is for the purpose of destroying the resisting spores, which are very likely to be present in the milk. After sterilization the whey is filtered through filter paper, and should be clear. There is then added to it 13¾ per cent. of gelatin. The material is then dissolved by a moderate heat, neutralized to the phenolphthalein by titrating and adding NaOH in the ordinary way. After neutralization the reaction is brought to 1.5 per cent. acid by adding 15 cubic centimeters of normal hydrochloric acid for each liter of the material. The white of an egg is added, the whole is boiled briskly for a few moments, the water of evaporation replaced (by weight), and the mixture filtered through absorbent cotton. The filtered solution is placed in test tubes, each containing *exactly 8 cubic centimeters*, and then is sterilized in steam upon three successive days in the usual manner.

A slight modification of the above has been commonly adopted. Where the gelatin is subsequently used, there is added to it considerable water (with the litmus solution and milk dilution), and this dilutes the food ingredients of the whey more than is desirable. To avoid this we proceed as follows: The sterilized milk whey is neutralized, and 10 per cent. gelatin added to it with the white of an egg. It is then cooked until 27 per cent. of its weight has evaporated, after which it is brought to the desired grade of acidity and filtered without replacing the water of evaporation. This water is subsequently replaced with the litmus solution and the diluted milk, as described below, giving a final solution of the desired strength.

Milk custard.—Thinking that possibly the rennet added to the milk might produce some deleterious action on the bacteria, a similar medium has been tried in which the casein is precipitated by the use of an egg. Milk is mixed with an egg, both the white and the yolk, and the whole is thoroughly boiled. The result of the boiling is a curdling of the milk, and after curdling the whole material is strained through cheesecloth, and the whey sterilized in the autoclav as above described. The further treatment is identical with the above, the only difference in the preparation of these two media being in the use of the egg rather than the rennet for the precipitation of the casein. Practically, the material is much more difficult to make than the whey gelatin.

Peptone culture media.—The third culture medium is the ordinary beef peptone gelatin such as is prepared for most bacteriological work and described elsewhere. This material is made with 13¾ per cent. of gelatin and placed in test tubes, 8 cubic centimeters exactly being placed in each tube. The reason for the high per cent. of gelatin and the exactness of the 8 cubic centimeters in the tubes will appear below.

METHOD OF USING THE ABOVE MEDIA.

The method of using any of the culture media above described with the litmus solution is as follows: Several tubes of any of the litmus culture media above prepared are melted, and into each by means of a sterilized pipette is placed 2 cubic centimeters of the litmus solution. The whole is mixed together by gentle agitation, giving 10 cubic centimeters of solution with a deep blue color. The mixture has a percentage of gelatin of about 11 per cent., this being the percentage which we have found most satisfactory for our purpose. The reason for using exactly 8 cubic centimeters of a 15 per cent. solution is that the mixture may be brought to 12 per cent. gelatin. It is evident also that if the litmus should prove to be weak, so that more than 2 cubic centimeters of the solution are required to give the proper depth of blue, a smaller amount of gelatin solution must be placed in each tube and a higher per cent. of gelatin. A more convenient way of adjusting this is, however, to use

more dry litmus in making the litmus solution, using a sufficient amount of litmus to make a solution deep enough to give the desired blue when mixed with the gelatin in the above proportions. A few tests with each lot of litmus purchased makes it possible to obtain always the same depth of blue when it is mixed with gelatin in proportions of 2 cubic centimeters to 8 cubic centimeters.

After the litmus is mixed with the gelatin, one cubic centimeter of the diluted milk to be tested is added to each tube, reducing the gelatin mixture to 10 per cent. The whole is thoroughly mixed, poured into petri plates, and allowed to harden. The plates are cultivated at 70° for six to seven days, if possible, before final study, and the final study is made with a hand lens and a compound microscope, using a 1½ inch objective.

COMPARATIVE EXPERIMENTS.

In testing the efficiency of different culture media it is necessary to have in mind that there are two points to be determined. 1. The value of the medium in determining the *number* of bacteria present in milk. For this purpose the medium which gives the highest count will be undoubtedly the best. 2. The value of the medium in *differentiating* the species of bacteria. The chief object of our experiments has been to determine not the total number of bacteria, which we regard as of comparatively little importance in milk, but the proportions of the different species of bacteria present in milk under different circumstances. For this reason, therefore, the matter of the differentiation of species is of much more significance than the matter of the total number of bacteria. In testing the culture media, therefore, more emphasis must be placed upon the successful differentiation of species than upon the detection of total numbers.

GRADE OF ACIDITY.

This was tested by making culture media of different grades of acidity and testing them by comparative experiments with the same lot of cream. Briefly the results were as follows: A solution neutral to phenol-phthalein or one with a reaction of .5 per cent. acid was unsatisfactory, the numbers of colonies

being small, and the differentiation not sharp. An acidity of 1 per cent. acid gave better results. There was very little difference between the results obtained with 1 per cent. and 1.5 per cent., although there seemed to be a small advantage in favor of 1.5 per cent. A medium 2 per cent. acid was again unsatisfactory. Hence the best grade of reaction was between 1 per cent. and 2 per cent., and we finally chose 1.5 per cent. as upon the whole a little more satisfactory than a lower grade. In all of our subsequent work this grade of reaction, 1.5 per cent. acid to the phenol-phthalein neutral point, has been chosen, and both the litmus solution and the gelatin medium have been brought to this point.

DIFFERENT CULTURE MEDIA.

Our next problem was to determine which of the media above mentioned is the best for the purpose of differentiation. To test this a sample of milk was diluted to a proper extent, usually about 300 times, and then one cubic centimeter of the dilution was placed in several tubes of each of the three kinds of gelatin culture above described and also into mixtures of the different kinds. We have used fresh milk rather than older milk, inasmuch as in the fresh milk the variety of bacteria is considerably greater than in samples of older milk, and consequently the differentiation is more difficult, and the test therefore a more rigid one. The three sets of tubes were poured into petri dishes, put aside at the ordinary room temperature, and allowed to develop until they were of a proper age for study. Each plate was then studied by itself, and the results tabulated and compared with one another.

The results of the comparative study of three series of plates cannot be satisfactorily expressed by tables. Although tables can give the total numbers of bacteria of each species distinguished in the different plates, they cannot express at all the sharpness of differentiation of the different kinds of colonies and do not give any idea as to which medium is best for this purpose. This can be determined only by actual examination of the plates and by learning from practice which type of plate is easiest to study and most satisfactory. Three of these comparative tables will be given below and will serve two purposes. They will illustrate the use of different culture media as

compared with one another and will at the same time indicate the extent of the error of this method of analysis. Each of the columns represents the analysis of the same sample of milk, and since the results are given in percentages, the columns would agree if the results were strictly accurate. The variations in the numbers in the respective columns represent the errors of the methods of analysis.

TABLE 14.

Comparison of culture media. Figures indicate percentages.

	Custard Gelatin.		Whey Gelatin.		Peptone Gelatin.	
	1.0% Acid.	1.5% Acid.	1.0% Acid.	1.5% Acid.	1.0% Acid.	1.5% Acid.
Total, - - - - -	11,700	12,900	12,150	13,200	17,700	14,850
Slow liquefiers (Group VII.),	9.6	6.8	23.1	12.6	14.1	15.1
Small lobed (Micrococcus),	—	—	—	2.0	—	—
No. 222 (Group VIII.), -	15.5	14.7	12.7	18.6	11.7	12.1
Group IV., - - -	39.9	35.1	35.5	37.3	56.2	47.5
Group II., - - - - -	—	—	—	4.1	—	—
Group I., - - - - -	7.9	5.7	12.7	2.9	5.3	5.0
Group V., - - - - -	20.2	27.9	9.1	15.5	9.9	8.2
Rapid liquefiers (Group VI.),	1.5	—	—	—	—	—
Group III., - - -	—	1.0	—	1.0	2.1	—
Miscellaneous, No. 1, -	3.2	6.7	3.7	2.0	.7	5.0
Miscellaneous, No. 2, -	2.2	—	1.1	—	—	1.0
Miscellaneous, No. 3, -	—	1.1	1.1	2.0	—	—
Miscellaneous, No. 7, -	—	1.0	—	—	—	—
Miscellaneous, No. 8, -	—	—	—	—	—	6.0
Undetermined, - - -	—	—	—	—	—	6.0

From this table it would appear that while peptone gelatin gave sometimes the larger bacteria count, it does not give as good a differentiation as either of those made from milk. This is shown chiefly by Group IV., which is decidedly larger with the peptone gelatin than with the other two. The Group IV. is a neutral group and will always increase in percentage as the differentiation of other groups becomes less sharp. Many of the acid bacteria of Groups I. and V. are evidently counted with Group IV. in the peptone gelatin plates. The only other considerable difference in the three media is in the percentage of Group V., which was much higher in the custard gelatin. But since our other experiments (see Tables 15 and 16)

showed no such result, we regard this as one of the incidental irregularities which are inevitably due to the bunching of bacteria together and the failure to distribute them uniformly. Beyond these differences a comparison of the analyses given shows that the results of the three media are not very different, and that the analyses agree moderately well.

The table shows clearly that it is impossible to distribute the bacteria through the milk in such a way that a cubic centimeter will give an average sample. For example, in column three the percentage of liquefiers is 23.1, while in column four it is 12.6, and in column two it is only 6.8. Now the liquefiers are always very easily distinguished and can never be confounded with other colonies. This difference must therefore indicate a difference in numbers and not a failure to properly differentiate the species. Such irregularities are to be expected. A microscopic study of a drop of milk shows that the bacteria have a tendency to cling together in masses, little bunches of the same species being found floating in the milk. In our analysis we endeavor to break these up as much as possible by thorough shaking, but we cannot expect to do this in all cases, and such little groups will occasionally produce such irregularities as those just pointed out. In other words, to get a strictly average sample of a lot of milk seems to be impossible, and at best the results of a differential analysis of milk will show occasional irregularities due to the grouping of bacteria. This fact, of course, detracts from the value of any single analysis, and greatly increases the amount of work necessary, since it is possible to rely only upon results that represent the average of many samples. The irregularities of the figures in Table 14 are much higher than usual, as will be seen from the two tables which follow.

Experiments of which Table 14 is a sample seemed to indicate that while peptone gelatin gives the larger bacteria count, either of the milk culture media gives a sharper differentiation. This does not show so well from the figures given in the table above as from a study of the plates, the difference being in the sharpness of the distinction of the colonies. In the milk culture the lactic bacteria produced rapidly a clear, sharp, very red colony, easily distinguishable from others, whereas in the peptone gelatin the same species produced a much less noticeable

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red, and one that was more difficult to distinguish from other types, particularly Group IV. Hence differentiation was considerably easier upon plates made from milk media than upon peptone plates. We next attempted to combine the media together for the purpose of obtaining, if possible, a medium that would give large numbers and at the same time a good differentiation. We used combinations of custard and peptone gelatin and of the whey and peptone gelatin, using half of each. The two following tables represent the results of these experiments. These tables are given in part for the purpose of showing the value of different media and in part to show the limitations in the accuracy of the method of qualitative analysis as adopted in our laboratory.

TABLE 15.

Comparison of different culture media, given in percentages.

	Peptone Gelatin.	Whey Gelatin.	Custard Gelatin.	Peptone and Whey Gelatin.	Peptone and Custard Gelatin.
Total number, - - - -	195,500	216,700	217,000	241,000	231,500
Slow liquefiers (Group VII.), -	8.3	12.6	15.4	6.6	11.4
Small lobed (micrococcus), -	4.5	10.6	13.9	17.1	18.7
No. 222 (Group VIII.), - -	7.1	14.2	3.7	6.3	5.3
Group IV., - - - - -	60.3	31.8	33.6	44.1	37.3
Group II., - - - - -	.8	3.8	5.6	.9	1.6
Group I., - - - - -	4.3	5.8	6.0	6.7	6.5
Group V., - - - - -	2.6	1.0	2.8	2.5	1.4
Rapid liquefiers (Group VI.),	1.5	.9	2.5	1.7	1.8
Group III., - - - - -	—	.2	.2	—	—
Miscellaneous, No. 1, - -	3.7	6.2	4.0	3.3	3.4
Miscellaneous, No. 4, - -	.5	.3	—	—	—
Miscellaneous, No. 5, - -	5.9	6.4	4.7	6.4	6.0
Miscellaneous, No. 6, - -	.5	—	—	—	—
Undetermined, - - - -	—	6.2	7.6	4.4	6.6

From these tables it is seen that a combination of peptone with the milk media produced results somewhat higher than any of them alone. The differentiation of the colonies was also found better in combinations of the different media than it was in the peptone alone, though no better than in the milk media alone. It will be seen also from the tables that there is in general a close similarity in the percentage of the different

TABLE 16.

Comparison of different culture media, given in percentages.

	Peptone Gelatin.	Whey Gelatin.	Custard Gelatin.	Peptone and Whey Gelatin.	Peptone and Custard Gelatin.
Total number, - - - -	202,000	191,700	210,000	180,000	230,000
Slow liquefiers (Group VII.), -	10.2	12.1	10.9	11.9	10.1
Small lob'd colony (micrococcus)	34.9	42.3	30.9	38.2	30.4
No. 222 (Group VIII.), - -	4.7	4.7	5.9	4.8	3.9
Group IV., - - - - -	12.3	12.4	11.1	13.3	13.2
Group II., - - - - -	3.6	12.3	11.6	18.7	9.3
Group I., - - - - -	1.0	.6	1.0	1.1	1.1
Group V., - - - - -	1.9	1.2	2.0	1.7	1.7
Rapid liquefiers (Group VI.), -	.2	.5	.1	.3	—
Group III., - - - - -	—	—	.1	.1	—
Miscellaneous, No. 1, - -	13.1	6.1	12.1	9.3	15.5
Miscellaneous, No. 2, - -	—	—	—	—	.2
Miscellaneous, No. 3, - -	.1	—	—	—	—
Undetermined, - - -	1.8	7.8	14.3	.6	14.6

species found in milk by the different culture media, and that the irregularities are less than in Table 14. While there are some considerable differences in the percentages given of certain species, especially Group IV. and Miscellaneous No. 1, they are less than in the experiment represented by Table 14.

In all of these tables it will be seen that the three or four miscellaneous species are given at the bottom. These are species present in very small numbers, appearing in some of the plates and absent from some others, a condition that would be inevitable in the case of a bacterium present in moderately small quantities.

The comparative value of the different media cannot well be given by tables. After a long series of tests with media, we concluded that the most satisfactory medium for all purposes, including both the quantitative and the qualitative analysis, was a mixture of the common beef peptone gelatin and the gelatin made from milk by the use of rennet. This was chosen rather than the custard gelatin, because it is very much easier to make and the results were about the same. In all of our subsequent work we have used this mixture, with results which have been satisfactory.

BACTERIA IN FRESHLY DRAWN MILK.

BY H. W. CONN.

Recent papers by Harrison and Cumming (Jour. Ap. Mic. M., p. 2030, 1903 and Rev. Gen. d. Lait. II., p. 457, 1903) have treated of the bacteria present in freshly drawn milk and have reached results in some respects quite at variance with those which have been obtained by others. In these experiments milk was drawn with careful aseptic precautions. The udder was carefully washed with a solution of 1 to 1000 mercury bichloride, the milk was drawn immediately into sterilized vials, which were closed at once, and was then studied by bacteriological methods. The data thus obtained were such as to give the number and to a certain extent the species of bacteria in milk drawn directly from the teats of the cow. The results of this paper, in brief, were as follows: The number of bacteria present in such milk was widely variable but usually very high. The highest number in one cow was 120,000, and the lowest in the same cow 24,080. A second cow gave only 100 to 500 per cubic centimeter. The species found in fore milk were several, but in all cases, according to the authors, 96 per cent. of them consisted of *Bact. lactis acidi I. and II.* (Conn, Nos. 206 and 202), and B. *aerolans* (Conn, No. 197), all of which are common typical lactic organisms. In other words, according to these authors, over 95 per cent. of the bacteria present in the fore milk of the cows upon which they experimented were typical lactic bacteria.

These results are quite different from those that have been obtained in recent years by others. Burr (Cent. f. Bact. II., VIII., 236, 1902), in experiments carried on in this place, concluded that the bacteria in the fore milk of cows contain the lactic organisms in only a very small percentage of cases. In

most cows this *Bact. lactis acidi* is absent, and when present it is present in very small numbers. Freudenreich (Rev. Gen. d. Lait II., p. 241, 1903), in a similar way, made a careful study of the species of bacteria found in fore milk and reached similar conclusions, being able to find the typical lactic organism, *Bact. lactis acidi*, only in very small numbers. Barthel (Rev. Gen. d. Lait. I., p. 505, 1902), performing similar experiments, reached similar results, and the experiments that have been more recently performed in our own laboratory have only tended to emphasize the conclusion previously reached that, at least in the animals which we have had the opportunity of experimenting upon, typical lactic organisms are present in only very small numbers in fore milk. This discrepancy between the results of Harrison and Cumming and those of others has led us to some further experiments upon the same subject, part of which are given in other papers in this report and call for a brief comment upon results. A brief summary of our experiments up to the present time may be given here, as indicating that the results obtained in Middletown and at Storrs are still at variance with those obtained by Harrison and Cumming.

Numbers of bacteria.—The first striking difference is in the numbers of bacteria which are found in the fore milk when the milk is drawn with proper precautions. A long series of experiments was performed at Storrs, see pages 52–62, in which moderate precautions were used. These consisted simply in washing the udder and the teats of the cow and drawing the milk into milk pails which had been thoroughly sterilized and were closed with the special cover, described in a previous paper. This, of course, did not exclude all bacteria coming from the air, for some would inevitably fall into the milk pail. The chance for external contamination was, therefore, very much greater than when the milk is drawn directly into a sterilized vial. The results, however, gave far lower numbers than those found by Harrison and Cumming. In the experiments given in other parts of this report, the average of about 70 experiments was 6,900 per cubic centimeter, the highest number being 48,000. These numbers were obtained without aseptic precautions, and with aseptic precautions which exclude

all air bacteria the average was only 250 per cubic centimeter, in *no case rising above 850*. These numbers agree well with those reported by Van Slyke at the Geneva Experiment Station (12th An. Rep. N. Y. Exp. Sta., p. 184, 1902).

It will be seen that, instead of concluding that the milk ducts furnish bacteria by thousands per cubic centimeter of milk, our experiments indicate that the uncontaminated milk contains only small numbers. From our experiments the chief contamination of milk would seem to be external; from those of Harrison and Cumming it would seem to be the milk ducts.

Species of bacteria.—The most striking difference, however, between the results that we have obtained and those of Harrison and Cumming is in the species of bacteria. It should be stated that our studies have involved individual tests of about one hundred cows and several scores of experiments upon the mixed milk of a herd of thirty cows. Moreover, they have been carried out both at Middletown and at Storrs, places about thirty miles apart. The results, therefore, are not isolated and dependent upon a small amount of data, but have been confirmed by some hundreds of experiments. It may be further stated that these hundreds of experiments practically *all* confirm each other, and whereas there are some variations in the percentage of lactic bacteria in milk freshly drawn, the numbers are always small and never approximate the conditions described in Harrison's experiments.

The most striking fact of our analyses compared with those of Harrison and Cumming is the small numbers of the lactic bacteria. Whereas Harrison found 95 per cent. or so of the bacteria belonging to the lactic types, we have found the numbers far smaller. The highest numbers were 70 per cent., and this only in two cases. Commonly there are less than 50 per cent., and in many cases below 30 per cent.

When a closer study is made of these lactic organisms, we find that in practically no instance do they consist of the three types which Harrison finds. We occasionally find *B. lactis aerogenes*, *B. coli*, and some other closely allied forms, but practically never either *B. lactis acidi I. or II.* This result has

been repeated so many scores of times without exception that we are convinced that it expresses a general truth, especially since it is confirmed by the work of Freudenreich and Barthel.

It is certainly a fact that in the milk of this vicinity the common lactic organism, *Bact. lactis acidi*, is not present to any great extent in the milk ducts and apparently is not present at all. What are the species of bacteria which are found in fresh milk in this region? A description of these species will be reserved for later publication, and only some general facts need be here given. Among them the bacteria found are, in most cases, *liquefying bacteria*, including both coccus forms and bacilli. These are sometimes abundant and sometimes comparatively few. The larger majority of bacteria found in the fresh milk are wholly neutral in their action on milk. They fail to produce acid, they fail to produce any enzyme for digesting milk, and when inoculated into milk produce no decomposition that is perceptible. There are several species of these neutral forms, including streptococci and short rods, the streptococci being in the majority. The types of colonies which these organisms produce in ordinary gelatin are not characteristic, so that the several types are not easily distinguishable from one another. In the milk of our region, then, the bacteria present in milk immediately drawn from the animal consist of neutral cocci and bacilli and a considerable proportion of liquefying organisms. There is a moderate percentage of lactic bacteria, including occasionally *B. coli and B. lactis aerogenes;* but *Bact. lactis acidi* (206 and 202) are very rarely found, and in very small numbers when present. One or two other species of unusual lactic bacteria are also frequently found.

What is the explanation of the difference between our results and those of Harrison and Cumming? Beyond much doubt a considerable portion of the difference may be attributed to the difference in actual conditions; for it is quite certain that the species of bacteria which are found in the milk ducts in one locality are different from those found in another and may be different even in animals in the same herd. I am inclined to think, however, that this is not the whole difference. The discrepancy seems too great to be due to difference in individual cows, and the results seem to be more properly explained by

the difference of *methods of analysis.* The methods used by Harrison and Cumming are not described in detail, but appear to consist in the use of *ordinary* gelatin in which the milk is inoculated, and then in the isolation from the gelatin of certain typical colonies and their subsequent testing by bacteriological methods. Such a method is quite inadequate for a qualitative analysis of the species of bacteria found in milk. The methods which are in use in our laboratory, and which are described in another place in this same report, enable us to determine with accuracy *all* the lactic organisms; but no gelatin plates which fail to contain litmus or some other similar material can be trusted to detect all the lactic organisms and distinguish them from others. The colonies produced by many lactic bacteria and those produced by the neutral forms above mentioned (our Nos. 194, 205, 90, and 224), are almost identical upon common gelatin. If the only method of detecting the organisms is by studying the common gelatin plates and picking out a few samples of colonies to be tested, the neutral forms which fail to produce acid would be, in nine cases out of ten, confused with the typical lactic bacteria. We are inclined to believe, therefore, that the discrepancy between the results of Harrison and Cumming and ours is due to the failure on their part to use a culture medium which will enable them sharply to differentiate lactic bacteria from others producing similar colonies in ordinary gelatin. Whether this be true or not, it is certain that in this locality, and if we may trust the work of Freudenreich and Barthel, in Europe also, milk as drawn freshly from the cow does not contain the *Bact. lactis acidi*, or contains it only in small numbers and shows usually only a comparatively small percentage of lactic bacteria.

GENERAL SUMMARY.

The most important conclusions which have been reached by the papers described in this report are the following:

1. For further advance in dairy bacteriology qualitative analysis of species must be substituted for quantitative analysis, the former promising to show a totally new series of facts concerning the problems of milk bacteria.

2. Freshly drawn milk contains a small number of lactic bacteria, the number varying from 10 to 60 or occasionally 70 per cent., usually below 30 per cent. In these cases, however, the lactic organisms present are rarely the typical dairy bacteria, *B. lactis acidi I. and II.;* these species being either absent or present in very small quantity in fresh milk. *B. aerogenes* is occasionally present, and also *B. coli*; other lactic bacteria which are of less significance in dairy problems constitute the lactic organisms of fresh milk.

3. At ordinary temperatures the few individuals of *B. lactis acidi* begin to grow rapidly as soon as the milk is drawn from the cow, and become more and more numerous each hour. At the end of 36 to 48 hours this species usually comprises 95 to 100 per cent. of the bacteria present in milk preserved at ordinary temperatures.

4. Market milk, as distributed in a small community where the milk producers are near the consumers, can be qualitatively analyzed by methods herein reported, and the analysis enables us to determine not only the number of bacteria, but also whether the milk containing large numbers is old milk with harmless species or fresh milk badly contaminated with suspicious forms.

5. The temperature at which milk is preserved is a factor of more importance as affecting the keeping property of the milk than is the original cleanliness in the dairy. When milk is drawn under ordinary conditions and has 3,000 or more bacteria per cubic centimeter, the number of bacteria found, unless there be more than 50,000, has very little to do with the keeping property of the milk; for no parallel can be drawn between the number of bacteria at the outset and the number found after one, two, or three days, nor between the number in fresh milk and the time of souring and curdling.

6. When, however, special aseptic precautions are taken to reduce the contamination of milk by external bacteria, a very great effect is produced upon the keeping property of the milk;

for the reduction of the numbers in fresh milk to 200 to 400 per cubic centimeter very decidedly increases its keeping property. Moreover, the reduction to these small numbers decreases the rapidity with which the bacteria grow, even those present not reproducing as fast as those found in ordinary milk. Such aseptic precautions keep out of milk the *Bact. lactis acidi* and materially decrease the rapidity of souring.

7. Great variations appear, in milk which is kept under identical conditions, as to the rapidity of souring, the time of curdling, the amount of acid that develops in the milk, and the number of bacteria that are present at the time of curdling. These variations are at present inexplicable.

THE NUTRITION INVESTIGATIONS OF THE STORRS EXPERIMENT STATION.

BY W. O. ATWATER.

Previous reports have explained that the Station has been engaged almost since its establishment in studies of the food and nutrition of man. That it began so early to make inquiries in this field is explained by the fact that the larger part of its more purely scientific work has been carried on at Wesleyan University and that the present writer, who was its director until September, 1902, had been much interested in the subject, and investigations in this line had been carried out in his laboratory for a number of years previous to the foundation of the Station. The earlier nutrition work of the Station was conducted in coöperation with the U. S. Department of Labor and consisted largely of studies of dietaries. Later, an especial appropriation was made by Congress for the study of the food and nutrition of the people of the United States, the responsibility of the work being vested in the Secretary of Agriculture, who assigned it to the Office of Experiment Stations of that Department and placed it in the immediate charge of the writer, then Director of the Station. The State legislature of 1895 provided an especial appropriation of $1,800 per annum to the Station mainly for work in this same direction, although provision was also made for study of the bacteria of milk. The Act of Congress providing appropriations for the Stations throughout the United States especially authorizes nutrition inquiries. It was therefore proper that a part of the fund received from the general government should be used for this purpose; and such procedure was the more appropriate for this Station because of gifts for the promotion of these investigations from friends of such inquiry who were interested in Wesleyan University, by whose generosity the work of the Station was greatly aided. When the Board of Trustees of the Connecticut Agricultural College, who were also the governing

board of the Station, found themselves able to provide for carrying out a larger share of the scientific work of the Station at Storrs, the nutrition work was left in the writer's hands. It thus comes about that the present report of the Station, like previous ones, contains accounts of nutrition inquiries.

What has been said makes it clear that the nutrition work of the Station is coöperative, the principal associates being Wesleyan University and the Department of Agriculture under whose general oversight and with whose special aid the inquiries of the Station are conducted. The inquiries are of various kinds, chief among them being studies of the chemical composition, digestibility and nutritive values of food materials, dietary studies and experiments with the respiration calorimeter. An illustration of one kind of investigation may be found in the articles in the present report on the analyses of flesh of poultry, and poultry as food. It should be said that of late comparatively few analyses of food materials have been made as part of these coöperative nutrition investigations, other than those required in the carrying out of digestion and metabolism experiments. There happens to be, however, a lack of information regarding the nutritive values of poultry used as food, and in view of the possibilities of poultry raising as a part of the agricultural industry of Connecticut it seemed desirable to learn more of this especial subject. Another illustration of the kinds of investigation conducted is found in the digestion experiments, the results of a large number of which were given in the preceding annual report of the Station. Numerous dietary studies have been reported in previous years, and a phase of the outcome of such studies in Connecticut and elsewhere is set forth in the article beyond, entitled Needs of the Body for Nourishment, and Dietary Standards. The inquiry of the most fundamental importance, however, is that which has been in operation for a number of years with the respiration calorimeter.

A description of this apparatus, its purpose and the method of its use, was given in the report of the Station for 1897. Under the title of "The Conservation of Energy in the Living Organism" the article beyond summarizes the results obtained in the study of one of a large number of questions by its use. A part of the data included in the above-mentiond article on

needs of the body for nourishment were also obtained from respiration calorimeter experiments. Detailed accounts of the work with this apparatus have been published from time to time by the Office of Experiment Stations of the U. S. Department of Agriculture. Such publication is appropriate not only because the wide distribution obtained is fitted to the general interest of the subject, but also because the resources of the Government Printing Office permit the publication of important statistical details which would be far too voluminous and expensive for an experiment station or private report. There is now in preparation a bulletin of the Office of Experiment Stations which gives the details of the late experiments with the respiration calorimeter and summarizes all of the general results obtained up to 1902.* The list of subjects treated in this bulletin includes the following:

Kinds, amounts and composition of food materials.

Digestibility of food and availability of energy.

Quantity and composition of products excreted by the lungs and skin, kidneys and intestine.

Summary of data of income and outgo of individual experiments.

Demand of the body for nourishment. Dietary standards.

Elimination of carbon-dioxid, water and heat.

Body temperature.

Heat production vs. heat elimination.

Estimates of amounts of oxygen consumed.

Respiratory and thermal quotients.

Amounts of energy derived from different nutrients.

Fats vs. carbohydrates as protectors of body material.

Fats vs. carbohydrates as sources of energy for muscular work.

Carbohydrates and fats vs. protein as sources of energy for muscular work.

Efficiency of the body as a machine.

Conservation of energy in the body.

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* U. S. Dept. Agr., Office of Experiment Stations, Bul. 136. Experiments on the Metabolism of Matter and Energy in the Human Body, 1901-1902. By W. O. Atwater and F. G. Benedict, with the coöperation of A. P. Bryant, R. D. Milner, and Paul Murrill.

While it would not be desirable even if it were possible for the Station to publish such masses of statistical detail as are given in the bulletin referred to, it may with propriety select some of the subjects and give brief abstracts of the results. This is done in the two succeeding articles.

The practical applications of these extended inquiries have been set forth to some extent in the reports and bulletins of the Station, and thus made available to the citizens of Connecticut. A much more extensive method of popularizing the results has been adopted by the Department of Agriculture in its "Farmers' Bulletins," a considerable number of which are devoted to the accounts of the nutrition investigations that are being carried out in different parts of the United States and of which those of the Storrs Station form a part. The work is thus made coöperative in its popular diffusion as well as in the experimental details and in the more technical publications. The bulletins here referred to are published by hundreds of thousands for free distribution and can be had by citizens of Connecticut, as of other states, by application either to members of Congress or to the Secretary of Agriculture. To have an important share in this large enterprise is a matter of congratulation to the friends of the Station and the State of Connecticut.

THE CONSERVATION OF ENERGY IN THE LIVING ORGANISM.

BY W. O. ATWATER.

In its material manifestations life consists of transformations of matter and energy. The plant gathers the elements it needs from soil and air, and builds them into its own substance. It does so "by grace and bounty of the sun," whose energy enables the plant to do the building and is stored in the substance of the plant. The ox eats the grass and transforms it into flesh, which makes our meat; we gather wheat and make bread; and when we eat the bread and meat their substance is transformed into the material of our bodies, or is utilized for the production of heat and muscular energy; thus the energy which comes from the sun becomes our energy for bodily warmth and work.

Experimental research has shown several ways in which the ingredients of ordinary food and body material serve as fuel. They are oxidized in the body; in the oxidation, their potential energy becomes kinetic and is thus made useful to the body; part of this kinetic energy appears as heat; another part appears as muscular work; in yielding energy by its own oxidation, food protects the material of the body and of other food from consumption.

Nutrition thus consists largely in transformations of food into body material and the ultimate transformations of both food and body material into energy. When matter is transformed energy is transformed also, and the transformations of both food and body material in nutrition are regulated largely by the needs of the body for energy. To learn the laws of nutrition we must know how these transformations take place; the study of them is the object of the experiments with the respiration calorimeter.

Two great laws govern the material world, the laws of the conservation of matter and of energy. In accordance with these laws matter and energy can be transformed, but they cannot be either created or destroyed by means known to man. Ever since the law of the conservation of energy was propounded, men of science have believed that the living organism must be subject to it, but the absolute demonstration has been lacking. The research by which this must be proved, if proved at all, is laborious and costly. Some late experiments, however, have, it is safe to say, indicated that the law does hold in the living organism; that when the energy of the food is transformed in the body, the income and outgo are the same. The experiments are made by measuring the material which the body burns, determining how much heat it would yield if burned directly with oxygen outside the body, and then finding just how much energy is produced when it is burned in the body.

Investigations by Rubner* in Germany and by Laulanie† in France had brought results fully in accordance with the law of the conservation of energy, but their experiments were made with small animals—dogs, rabbits, etc., and were comparatively few in number; the experimental periods were rather short; the analyses of food, drink, and excreta were not carried out in great detail, and no experiments were made in which external muscular work was involved. It was felt that the demonstration would be more nearly complete and on the whole much more satisfactory if the subjects of the experiments could be men, and preferably men who were familiar with the methods of scientific research; if the experimental periods could cover several days each instead of being limited to a day or a few hours; if complete analyses could be made of the food, drink, and excretory products, the heats of combustion of the unoxidized materials being likewise directly determined in each case; if the experiments could cover different conditions as regards food and fasting, work and rest; if external muscular work could be performed and measured and finally if the experiments could be repeated with the same subject and with different subjects. So extensive a program was

* Ztschr. Biol. 30 (1894), p. 119 *et seq.*
† Arch. Physiol. Paris (1898), p. 748.

perhaps unnecessary for the study of a question about which there was really little doubt, and some persons may even doubt whether the experiments which have been reported suffice for the final and absolute demonstration that the law of the conservation of energy always obtains in the body; but it will be worth while to consider here what the experiments are and what they do show.

The experiments here considered, which were much more elaborate than those referred to above, were carried on within the past four years by the writer and associates at Wesleyan University, in coöperation with the Storrs Experiment Station and the U. S. Department of Agriculture. In these the quantities and potential energy of the materials burned in the body have been measured, as has also the energy given off from the body in the forms of both heat and muscular work. The agreement between the potential energy (heat of combustion) of the material oxidized in the body and the kinetic energy given off from the body in the forms of heat and (the heat equivalent of) external muscular work was so close as to imply that practically all the energy of the material burned in the body was transformed into measurable kinetic energy in accordance with the law of the conservation of energy.

The experiments were made with a respiration calorimeter which was especially devised for research of this kind. The apparatus serves to measure the materials received and given off from the body, including the products of respiration, and is thus a "respiration apparatus;" it also serves to measure the heat given off by the body and hence is a form of calorimeter. To indicate this two-fold purpose it is called a "respiration calorimeter." As accounts of this apparatus and of methods and results of experimenting with it have been published in detail elsewhere* a brief description will suffice here.

* In the following bulletins of the Office of Experiment Stations of the United States Department of Agriculture: No. 44, Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism with a Respiration Calorimeter of Special Construction, by W. O. Atwater, Ph. D., C. D. Woods, B. S., and F. G. Benedict, Ph. D.; No. 63, Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body, by W. O. Atwater, Ph. D., and E. B. Rosa, Ph D., pp. 94; No. 69, Experiments on the Metabolism of Matter and Energy in the Human Body, by W. O. Atwater, Ph. D., and F. G. Benedict, Ph. D.. with the coöperation of A. W. Smith, M. S., and A. P. Bryant, M. S., pp. 112; No. 109, Experiments on the Metabolism of Matter and Energy in the Human Body, 1898-1900, by W. O. Atwater, Ph. D., and F. G. Benedict, Ph. D., with the coöperation of A. P. Bryant, M. S., A. W. Smith, M. S.. and J. F. Snell, Ph. D. See also articles in preceding reports of this Station.

THE RESPIRATION CALORIMETER AND METHODS OF EXPERIMENT.

The apparatus includes a copper walled chamber about seven feet long, four feet wide, and six and one-half feet high, in which the man who serves as subject of the experiment lives during a period of four to twelve days and nights. An opening in the front of the apparatus, which is sealed during an experiment, serves as both door and window, and admits ample light for reading or writing. A smaller opening in the rear of the apparatus, called the food aperture, having tightly-fitting caps on both ends, is used for passing food, drink, excreta, and other materials into and out of the chamber. There is a telephone by which the subject may communicate with those outside. The chamber is furnished with a chair, table, and bed, each of which may be folded up and set aside when not in use. A stationary bicycle is also supplied when the subject is to do muscular work during the experiment. Air is kept in circulation through the chamber at the rate of not far from two and one-half cubic feet a minute. Thus, while the dimensions of the chamber are rather small, the subject finds nothing particularly disagreeable or uncomfortable in his sojourn within it, save for the restricted space and the monotony of the prescribed daily routine. But so little are these felt that each of the five men who have thus far sojourned in the calorimeter has found it a very tolerable place of residence and has been perfectly willing to repeat the experience. It may, therefore, be considered that the conditions are not sufficiently abnormal to affect the results of the experiments. This is an important consideration.

The circulation of air is effected by a special pump, which measures the volume of the ventilating current and at regular intervals draws measured samples of the outgoing air for analysis. At the same time samples of the incoming air are also taken for analysis. From these determinations the amounts of respiratory products—carbon dioxid and water—given off by the subject may be computed.

Heat is constantly given off within the chamber by the man's body, whether he is at work or at rest. When he is at rest, *i. e.*, doing no external muscular work, there is nevertheless a

great deal of muscular work going on within his body. Even when he is asleep the organs of respiration, circulation and digestion are active. The energy of the internal work is transformed into heat in the body and leaves the body as heat. This is proven by the fact, explained beyond, that when the body is at rest the heat it gives off is equal to the potential energy (heat of oxidation) of the material oxidized in the body.

When the man is working the bicycle, part of the power which he applies to the pedals is transformed into the heat of friction of the machine, but the larger part is transformed into electrical energy by means of a dynamo connected with the bicycle. The electrical current thus produced by the bicycle-dynano passes through a lamp and is converted into heat. In this way all of the external muscular work done, *i. e.*, all the power applied to the pedals, is transformed into heat within the chamber. Arrangements are made for measuring the heat of friction and also the electrical current produced by the bicycle-dynamo. The latter therefore serves as an ergometer for measuring the external muscular work.

We warm our houses in winter by a current of hot water which passes through radiators by which the heat is radiated into the rooms. We may hereafter learn to cool them in summer by the opposite process, *i. e.*, by passing cold water through the pipes and making them absorbers, so that the water will carry away the heat. Precisely this is done in the respiration calorimeter. A copper pipe passes around the chamber close to the walls; through this flows a current of cold water and by regulating the temperature and rate of flow of the water current, the heat is absorbed and carried out of the chamber as fast as generated. The temperature within the chamber is thus kept at a point agreeable to the subject and remains almost absolutely constant—indeed the variations are often within a single degree during the whole twenty-four hours.

The diet during the experiment is uniform from day to day. All food and drink passed into the chamber, and all solid and liquid excreta passed out, are carefully weighed, sampled and analyzed. By comparing the chemical elements and compounds received by the body in food, drink and inhaled air

with those given off in the solid, liquid and gaseous excretions from the body, it is possible to strike a balance between the total income and total outgo of matter in the body and to determine whether it has increased or diminished its store of material. In this way a gain or loss of even a small fraction of an ounce of body fat or protein during a period of one or several days can be detected and measured.

The above indicates the method of investigating the metabolism of matter in the body. It consists practically in measuring the income and outgo of matter and striking the balance between the two. At the same time it is desirable to study the metabolism of energy. This is done likewise by determining the balance of income and outgo. The measurements made in these investigations are in terms of heat, since other forms of energy may be transformed into heat. To this end it is necessary to know how much energy is taken into the body in food and drink, how much is given off unused in the solid and liquid excreta, and how much is transformed in the body and given off in the forms of heat and external muscular work.

So far as we know the only energy received by the body is the potential energy of the food, and the only forms in which it leaves the body are (1) partly in the potential energy of the unoxidized residues of food and body material which are eliminated in the solid and liquid excreta, but (2) chiefly in the kinetic energy resulting from the oxidation of material in the body.

The only forms in which kinetic energy is known to leave the human body are heat and external muscular work. Some animals, as the electrical eel, can give off small amounts of electrical energy; others, as the firefly, emit minute quantities as light; but they are exceptional. It has been surmised that mental work and nervous tension may represent forms of physical energy analogous to light, heat and other forms now known, just as the X-ray represents a form of energy unknown until a few years ago. But there is no experimental proof for this theory and it is opposed by the fact, explained beyond, that the energy given off from the body in the forms of heat and external muscular work is found to equal the potential energy of the materials oxidized in the body.

The potential energy of the food and excretory products is measured by the amount of heat generated when these substances are burned outside the body, that is by their heats of combustion, as learned by burning them with oxygen in an apparatus called the bomb calorimeter. The measurements of the kinetic energy given off from the body are made by means of the respiration calorimeter. The principle used in the measurement of energy by the respiration calorimeter is this. In the rest experiments, practically all the kinetic energy leaves the body as heat. In the work experiments part is put forth as muscular power applied to the pedals of the bicycle-dynamo, which transforms this external muscular energy into heat and, as an ergometer, measures its amount. The problem is to measure the whole heat including that which left the body as heat and that which resulted from the transformation of the muscular work. The method consists in collecting this heat for measurement, and at the same time providing that there shall be no gain or loss in the amount.

The chamber of the calorimeter is enclosed by double metal walls, which are surrounded on all sides by walls of wood with air spaces between, so that the temperature within the chamber is not appreciably affected by changes in the temperature of the room outside. Very delicate electrical devices show changes in the temperature of the metal walls; and devices for heating and cooling the walls are arranged so that their temperature may be kept as near that of the interior of the chamber as desired, and the very small amounts of heat that may pass through them into or out of the calorimeter may be made to counterbalance each other. The temperature of the ventilating air current is also regulated so that neither more nor less heat is taken in than is brought out. Accordingly there is no gain or loss of heat either through the walls of the chamber or by the ventilating air current. The heat produced within the chamber is that from the energy of the material oxidized in the man's body. The only way this heat can escape is by the proper agencies for carrying it out and measuring it.

These agencies are two, water vapor and the cold water current. A small portion of the heat generated within the chamber is carried out by water vapor in the ventilating air current.

The excess of vapor in the air that leaves the chamber over that in the air that enters it represents water which has been given off as vapor from the body of the subject, and has required heat to vaporize it. The amount of heat thus carried out of the chamber is computed from the amount of water vapor and the temperature at which it leaves the chamber.

The larger part of the heat generated within the chamber is absorbed and carried out by the current of cold water, above referred to as flowing through a copper pipe around the interior of the chamber. The cooling surface of the pipe is increased by thin disks of copper fastened at close intervals along the coil. The water enters the chamber at a low temperature, passes through the copper coil, absorbs heat from the chamber and passes out at a higher temperature. The quantity of water that passes through the coil, and the difference between the temperatures at which it enters and leaves the coil, are carefully determined, and show how much heat was thus brought out of the chamber. Adding the heat brought out by the water vapor in the ventilating air current to the heat brought out by the water current we have the whole heat produced in the chamber. This is the measure of the kinetic energy which resulted from the oxidation of food and body material in the man's body. In other words, it is the energy which he transformed; or to use another expression, it is the measure of the metabolism of energy in his body.

So delicate are the measurements of temperature of the air within the chamber, and of the metal walls, that the observer sitting outside the apparatus and noting the changes every two or four minutes, immediately detects a rise or fall of even one one-hundredth of a degree. For instance, if the man inside rises to move about, the increase in the heat given off from his body with the muscular work involved shows itself in a rise of temperature, which the observer immediately detects.

To complete the records made by the observers, the subject himself keeps a diary in which he records periodical observations of his weight, pulse-rate and axillary or sub-lingual temperature, together with any statements which may be of service in interpreting the results of the experiments.

The net income of energy of the body is computed from the energy of food, drink, solid and liquid excretory products, and body material stored or lost, an allowance being made for slight changes in temperature of the apparatus and the body during the experiment. The net outgo is measured by the apparatus. By comparing these the balance of income and outgo of energy is found.

The data for the metabolism of matter and of energy, obtained as explained above, taken in connection with what is known of the physiological processes that go on in the body, give more accurate information than can be otherwise obtained regarding the ways in which the food is used in the body, the quantities of different food ingredients that are needed to supply the demands of the body, the different conditions of rest and work, and the comparative nutritive value of different food materials.

THE ACCURACY OF THE APPARATUS AND METHODS.

Two methods of testing the accuracy of the apparatus are employed. By one method known amounts of heat are generated electrically within the chamber, and the heat is measured by the apparatus. In this way its accuracy as a calorimeter only is tested. By the second method known amounts of ethyl alcohol of known purity and composition are burned completely within the chamber, and the amounts of water, carbon dioxid, and heat resulting from the combustion of the alcohol are determined by the apparatus. In this way its accuracy both as a respiration apparatus and as a calorimeter is tested. In the average of five electrical tests the amount of heat measured by the calorimeter was 100.01 per cent. of the amount generated by the electric current. The averages of the results obtained in seventeen alcohol tests are summarized in the following table:

The results thus indicate that the respiration calorimeter is an instrument of precision and that the determinations of carbon dioxid, water, and heat produced within the chamber of the apparatus are sufficiently accurate for experiments with the living subject.

TABLE 17.

Summary of results in which alcohol was burned in the calorimeter.

	Carbon dioxid.	Water.	Heat.
	Grams.	Grams.	Calories.
Amount required, - - - - - -	19,239.8	12,264.4	64,554.1
Amount found, - - - - - -	19,206.9	12,379.1	64,513.3
Ratio of amount found to amount required,	99.8%	*100.9%	99.9%

* After the completion of the later experiments a slight leak was found in the "valve box" through which the outgoing air current passed on its way to and from the "freezers," and by which water, condensed on the outside, may have entered. There is every reason to believe that the quantity of water actually found was thus made too large by a fraction of 1 per cent. In the average of the first nine experiments the amount of water found was 100.6 per cent. of that required. As an alcohol check test was generally made between each two metabolism experiments or series of experiments we have a means of knowing when the leak began to affect the results and the amount of the error introduced. See Bulletin 109 of the Office of Experiment Stations, above referred to.

EXPERIMENTS WITH MEN.

As already suggested, the first purpose in the original planning of these investigations was to develop an apparatus and method for the measurement of the energy transformed in the body. The underlying thought was that if these measurements could be made accurately it might be possible to learn whether the law of the conservation of energy obtains in the living organism; and if this could be accomplished the principle and apparatus could be utilized for a more successful study of some of the fundamental laws of nutrition than would otherwise be possible. The purpose of the following discussion is to consider what evidence the results of the experiments thus far made with the respiration calorimeter furnish regarding the application of the law of the conservation of energy to the living body.

The first satisfactory experiments with men in the apparatus were made in 1896, although there has been several preliminary trials, the data from which were not sufficiently complete. Between February, 1896, and May, 1902, inclusive, 55 experiments, covering all told 171½ days, were carried out. In the first four of these the balance of income and outgo of matter only was determined; but in all the others the measurements of energy were also made. All but six of the latter give results bearing on the question here under discussion; the omission of these six being explained below.

The metabolism experiments included in this discussion comprise two classes. (1) Those in which the subjects were at rest, *i. e.*, had no more exercise than was involved in dressing and undressing, and caring for the furniture, food and excreta; and (2) those in which they were engaged in more or less severe muscular work on a bicycle-dynamo apparatus devised for measuring the amount of work performed.

Five different men have served as subjects in these experiments, all of them young and in excellent health. E. O. was a Swede by birth, who has received his training in laboratory work in connection with the respiration calorimeter and related investigations and is now employed in this laboratory as analyst and assistant. The rest were university-bred men and natives of the United States, except J. F. S. who was a Canadian. O. F. T. and J. F. S. were chemists and A. W. S. was a physicist, all three being assistants in this laboratory; J. C. W. was a student in Wesleyan University at the time of the experiments with him.

INCOME AND OUTGO OF ENERGY IN THE BODY.

These experiments compare the amounts of potential energy in the materials actually oxidized in the body with the amounts of kinetic energy given off from it, either as heat alone in the rest experiments or as heat and external muscular work in the work experiments.

In the rest experiments there was no considerable amount of external muscular work. The little that was done would naturally be converted into heat—as, for instance, in the impact of the foot upon the floor in stepping, or of the body upon the chair or bed in sitting or lying down. The heat thus imparted to the floor, chair, or bed would naturally find its way to the heat absorbers, and would thus be carried out with the heat given off as such by the body. Roughly speaking, we may say that all the potential energy made kinetic in the body by the oxidation of food and body material left the body as heat, and that this made the net outgo of energy.

In the work experiments a certain amount of energy is given off as external muscular work, and this added to the heat given off from the body makes the net outgo.

Table 18 compares the net income and outgo of energy in 45 of the 51 experiments in which the balance of energy was determined, namely, Nos. 5–55, the omissions being the fasting experiments with one of the subjects, J. C. W., in which the uncertainty as to the amount of carbohydrates (glycogen) lost by the body makes the comparison doubtful, and Nos. 50 and 55, also with J. C. W., in each of which there was an evident error in the heat measurement.

TABLE 18.

Comparison of income and outgo of energy in 45 metabolism experiments covering 143 experimental days. Average amounts per day.

SUBJECTS AND KIND OF EXPERIMENTS.	Number of experimental days.	Net income (potential energy of material oxidized in body).	Net outgo (kinetic energy given off from body).	Difference (in terms of net income).	
	Days.	Cal.	Cal.	Cal.	%
ORDINARY DIET.					
Rest Experiments.					
7 experiments with E. O., - -	25	2,268	2,259	— 9	— .4
1 experiment with A. W. S., - -	3	2,304	2,279	—25	—1.1
3 experiments with J. F. S., - -	9	2,118	2,136	+18	+ .8
1 experiment with J. C. W., - -	4	2,357	2,397	+40	+1.7
Av. 12 experiments with 4 subjects, -	**41**	**2,246**	**2,246**	—	—
Work Experiments.					
2 experiments with E. O., - -	8	3,865	3,829	—36	— .9
4 experiments with J. F. S., - -	12	3,539	3,540	+ 1	—
14 experiments with J. C. W., - -	46	5,120	5,120	—	—
Av. 20 experiments with 3 subjects, -	**66**	**4,682**	**4,676**	**— 6**	**— .1**
Av. 32 rest and work experiments, -	**107**	**3,748**	**3,745**	**— 3**	**— .1**
SPECIAL DIET.					
Rest Experiments.					
6 experiments with E. O., - -	17	2,313	2,319	+ 6	+ .3
3 experiments with A. W. S., - -	6	2,308	2,356	+48	+2.1
1 experiment with J. F. S., - -	3	2,124	2,123	— 1	—
Av. 10 experiments with 3 subjects, -	**26**	**2,290**	**2,305**	**+15**	**+ .7**
Work Experiments.					
1 experiment with E. O., - - -	4	3,922	3,928	+ 6	+ .2
2 experiments with J. F. S., - -	6	3,583	3,552	—31	— .9
Av. 3 experiments with 2 subjects, -	**10**	**3,719**	**3,702**	**—17**	**— .5**
Av. 13 rest and work experiments, -	**36**	**2,687**	**2,695**	**+ 8**	**+ .3**
ALL DIETS.					
Av. 45 rest and work experiments, -	**143**	**3,481**	**3,481**	—	—

The figures for income and outgo of energy require a word of explanation. A distinction is here made between the total* income, which is represented by the potential energy of the food, and the net income, which is the energy of the material actually oxidized in the body. This energy of net income is represented by the available energy of the nutrients of the food (*i. e.*, potential energy of total food less that of the urine and feces) minus the potential energy of the material gained or plus that of material lost by the body when the latter is not in nitrogen and carbon equilibrium. The total energy of outgo would be the kinetic energy given off from the body in heat and as external muscular work plus the potential energy of the unoxidized materials in the urine and the feces. The net energy of outgo consists of the heat given off and the external muscular work done. The balance of income and outgo is best shown by the net rather than by the total quantities, as is the case in Table 18.

It is to be remembered that the figures for net income of energy represent the heat of combustion of the material actually oxidized. This material consists mainly of the digestible portion of the food of which the amount and heat of combustion are found by direct determination. To its heat of combustion is added that of the material lost, or from it is subtracted that of the material gained by the body. The amounts of materials gained or lost are determined from the gain or loss of nitrogen and carbon, and their heats of combustion are calculated by the use of factors based upon direct determination of the heats of combustion of similar substances. The figures for net outgo are the results of direct experimental measurement. In other words, the net income of energy is mainly and the net outgo entirely the results of direct determinations.

A common usage is followed in applying the term "potential energy" to the energy latent in the food and body material oxidized. Whether chemical energy would or would not be a more correct expression no attempt is here made to decide. Ordinary usage is also followed in expressing potential energy in terms of heat—*i. e.*, as calories—thus employing a unit of kinetic energy for the measurement. This though unsatisfactory is

* The terms "total" and "net" here applied to income and outgo of material and energy are used for present convenience, and may in future reports be replaced by more satisfactory expressions.

unavoidable, since we have neither the means for measuring potential energy as such, nor a unit for expressing the measurements if they were made. The use of heat of oxidation for the measure is especially appropriate here, since the energy is liberated mainly by oxidation and appears chiefly or entirely as heat.

If the law of the conservation of energy obtains in the living organism, the net income and the net outgo of energy should be the same. In such physiological experimenting, however, it would be hardly fair to expect the figures for the two to agree for each day of a given experiment or for each experiment as a whole, even if the measurements with the respiration and bomb calorimeters are exact. There may be errors in the estimates of the amounts and heats of combustion of the materials actually oxidized. Variations due to irregularities of the physiological processes of the body are unavoidable and may materially affect the results. For instance, the calculations assume that the quantities of material in the alimentary canal and the amounts of carbohydrates in the body as a whole are the same at the end as at the beginning of each day or experiment, whereas they may differ considerably and the differences would materially affect the results. But it might be hoped that, if the methods are correct, these errors would tend to counterbalance one another in a series of experiments, and that, in the average of a sufficiently large number, the errors would thus be offset, so that the income and outgo would be very nearly the same.

Exactly this is the case in the data here reported. The variations for individual days, and even those for the individual experiments, as shown in the detailed tables in this and the previous bulletins, are not inconsiderable, but considering the average of all the experiments the agreement is very close. Thus, in the 25 days of the seven rest experiments with ordinary diet with E. O., according to the figures for the individual days the net outgo varies from 165 calories below to 194 calories above the net income. Expressed in percentages of net income, the range here is from —6.5 to +9.1 per cent. Both these extremes occurred on the first days of the respective experiments, and in general, it may be said that the results for the first day of an experiment are found to be less satisfactory

than those for the succeeding days. Considering each experiment as a whole, and comparing the averages of the several experiments one with another, the range of variation is less. Here the net outgo varies from 103 calories below to 62 calories above the net income per day. Expressed in percentages of net income, the range is from —4.1 to +2.9 per cent. But in the average for the nine experiments the figures for the net income and outgo are practically the same, being 2,268 and 2,259 calories, respectively.

The discrepancies in the individual experiments with E. O. are the largest we have found. They occurred in the early experiments, which, however, were largely given up to the development of the experimental methods. In the later experiments, especially those with J. C. W., the variations were much smaller. The four widest variations in single days in the experiments included in the table above being from +231 to —258 calories, or from +4.6 to —4.7 per cent. and the four widest in the individual experiments, including more than one day from +157 to —96 calories or from +3.1 to —2.1 per cent. of the net income in each case.

The way in which the errors compensate each other is illustrated by the averages for income and outgo in Table 18, these averages being obtained, not by averaging the averages of individual experiments or groups of experiments, but by dividing the sum totals in each class by the corresponding numbers of days, as in the instance above cited. The sum totals from which the averages for the several classes of experiments in Table 18 were obtained are given below. The experiments with J. C. W. were the latest and therefore represent the advantage of accumulated experience in the development of apparatus and method.

In the average of the twelve rest experiments with ordinary food, covering 41 days, the sum total of the figures of daily income is 92,101 and for outgo 92,118 so that when the averages per day are found by dividing these numbers by 41, omitting fractions of a calorie, the figures for the two are the same, namely, 2,246 calories. A similar identity is found in the work experiments with J. C. W., for in the average of all the 32 experiments, covering 107 days, with ordinary diet, the daily income is 3,748 and the outgo 3,745 calories, making a difference of 3 calories or hardly 0.1 per cent. of the whole.

TABLE 19.

Total income and outgo of energy in metabolism experiments with the respiration calorimeter.

SUBJECTS AND KIND OF EXPERIMENTS.	Duration.	Income.	Outgo.	Difference in terms of net income.	
ORDINARY DIET.	Days.	Calories.	Calories.	Calories	%
Rest Experiments.					
7 experiments with E. O., -	25	56,700	56,467	—233	— .2
1 experiment with A. W. S., -	3	6,912	6,837	— 75	— .9
3 experiments with J. F. S., -	9	19,059	19,226	+167	+ .9
1 experiment with J. C. W., -	4	9,430	9,588	+158	+1.7
Total 12 experiments, 4 subjects,	**41**	**92,101**	**92,118**	**+ 17**	—
Work Experiments.					
2 experiments with E. O., -	8	30,919	30,631	—288	— .9
4 experiments with J. F. S., -	12	42,566	42,484	— 82	— .2
14 experiments with J. C. W., -	46	235,497	235,507	+ 10	—
Total 20 work experiments, 3 sub.,	**66**	**308,982**	**308,622**	**—360**	**— .1**
Total 32 rest and work exp., 4 sub.,	**107**	**401,083**	**400,740**	**—343**	**— .1**
SPECIAL DIET.					
Rest Experiments.					
6 experiments with E. O., -	17	39,313	39,424	+111	+ .3
3 experiments with A. W. S., -	6	13,851	14,139	+288	+2.1
1 experiment with J. F. S., -	3	6,373	6,370	— 3	—
Total 10 experiments, 3 subjects,	**26**	**59,537**	**59,933**	**+396**	**+ .7**
Work Experiments.					
1 experiment with E. O., - -	4	15,688	15,710	+ 22	+ .1
2 experiments with J. F. S., -	6	21,497	21,309	—188	— .9
Total 3 experiments, 2 subjects, -	**10**	**37,185**	**37,019**	**—166**	**— .4**
Total 13 rest and work exp., 3 sub.,	**36**	**96,722**	**97,012**	**+290**	**+ .3**
ALL DIETS.					
Total 45 rest and work exp., 4 sub.,	**143**	**497,805**	**497,752**	**— 53**	—

In the rest experiments with special diet the average daily outgo exceeded the income by 15 calories; in the work experiments it fell short by 17 calories; in the average of both work and rest experiments (18, covering 36 days) there was an excess of 8 calories or 0.3 per cent. of the whole.

Considering the results of all the experiments the difference is 55 calories in nearly 500,000 or about 1 in 10,000; in those with J. C. W. alone, which were the latest experiments and are believed to be more satisfactory than those previously made, it was about 1 in 20,000. It is clear that with increase

in experience and in the number of experiments the total averages of income and outgo approach each other more nearly and that the grand totals may be regarded as identical.

Of course such discrepancies as have been pointed out are far within the limits of experimental error and physiological uncertainty. As we said in a similar summary in a previous publication,* the agreement of average results is much closer than was originally hoped for, and it is by no means certain that future averages will show so exact a balance. The electrical and alcohol check tests described earlier, (page 112) show that the measurements of energy by the apparatus, though subject to minor errors in short periods, become nearly exact when several tests are averaged.

It seems certain that the respiration calorimeter itself is an apparatus of precision. The results reached by its aid are fully as accurate and reliable as those ordinarily obtained in the use of what are considered well developed forms of apparatus and methods in the chemical laboratory. To be sure, they are not equal in refinement to those used in the most accurate determinations of atomic weights, and they do not compare with the best physical measurements; nor are they yet by any means perfected as agencies for the special forms of research for which they were intended. The errors found in the results of individual tests are much larger and more numerous than is to be desired and attempts toward improvement are constantly made. Indeed much more labor has been given to the development and testing of apparatus and methods during the past eleven years than to actual experiments with men, and much more will have to be done in coming years to the same end. The direct determination of the amount of oxygen used in metabolism is one of the problems which surely needs solving and on this we are now working. But so far as the measurements of the energy given off from the body in the form of heat and the heat equivalent of muscular work are concerned the apparatus serves its pupose very well.

The same may be said of the bomb calorimeter as developed and used in this laboratory for the measurement of the potential energy of food and unoxidized excreta. This means that the net outgo of energy is measured with reasonable accuracy, especially when the results for long periods are available.

* Connecticut (Storrs) Station, Rpt., 1900, p. 129.

The measurements of net income are less certain because of the sources of error on the physiological side to which reference has been frequently made in these discussions. It seems probable that the chief of these uncertainties are those due to (1) the amounts of material in the alimentary canal, which may vary considerably from day to day at 7 A. M. when the experiments begin and end; (2) the possible error in assumed composition of protein and fats gained or lost in the body, though this error is probably small; and (3) the variations in the proportions of carbohydrates (glycogen) in the body which are not definitely measured in these experiments. The direct determination of oxygen it is hoped will help to remove this difficulty in future work. Meanwhile it seems safe to say that in the investigations here summarized the length of the experimental periods, the repetitions of the experiments with the same subject and with different subjects, and the number of results included in the averages, give to the latter an authority that cannot well be disputed. It seems fair to assume, therefore, that the figures for income of energy as summarized in Table 18 are not far from correct.

It is probably useless to hope that the transformations of matter and energy in the body will ever be measured with the accuracy of chemical and physical processes in the laboratory, especially in individual experiments of short duration. Certainty and exactitude must be sought in repeated and long-continued series. This statement applies to comparisons of income and outgo of energy. The net outgo may be measured exactly with the respiration calorimeter, but the net income is influenced by physiological factors for which there is little hope of exact determination except with aid of "the might of average figures" from numerous experiments. But with such repetitions reasonably close results can be obtained. It would seem that this consummation has been approached if not attained in the experiments with men above described.

The agreement of the totals and averages of income and outgo of energy in the different classes of experiments as shown in Table 18 can hardly be without significance. Reduced to their simplest terms, the results of these experiments show that the energy given off from the body in the two forms of heat and external muscular work equals the potential energy

of the materials oxidized. The natural inference is that practically all the energy transformed in the body appears as heat and external work. Two possibilities stand in the way of the acceptance of these results as a positive demonstration of the conservation of energy in these experiments and the natural corollary that it must obtain generally in the living organism. The first is that the measurements of energy may have been inaccurate. As regards this enough has been said to show the great improbability of any considerable error in the measurements of either income or outgo. The other is that some form of kinetic energy concerned in the transformations may have escaped measurement. If there be such it must have belonged to the outgo. The question then is, was any form of kinetic energy other than heat and muscular work produced within the body and given off by it?

Light and electrical energy are emitted by some of the lower animals, but it can hardly be assumed that any considerable amount of either is given off from the human body under ordinary conditions. It has been suggested that intellectual activity and nervous tension may be manifestations of some special forms of physical energy, the character of which is not yet understood. If such be the case any energy which is due to internal, mental, or nervous work must be transformed within the body, and unless there is some form of storage of which we have no conception it must be eliminated. It might be transformed into heat and leave the body in that form, as is the case with the energy of internal muscular work; it would then be measured with the other heat given off from the body. Or it might be eliminated in some other form unknown to us. In that case it must either pass through the copper wall of the respiration chamber without being changed to heat or it must have been changed to heat and measured, provided the quantity was large enough for measurement. In other words, the quantity must either have been extremely minute or it must be something the nature of which physical research has not revealed.

The theory has been lately advanced that the body emits some form of energy in which rays of great wave length are concerned, and recent discoveries and conjectures regarding such forms of energy are of a kind to incite if not encourage

such speculative hypotheses; but here again any acceptance of the common views regarding the laws of physical energy compels the assumption that if the energy of this sort is emanated from the body, the whole amount must be at most very slight and the quantity that could pass the copper walls in the experiment reported without being measured as heat must be not only within the limits of experimental error, but also too small for measurement by any ordinary means.

The conclusion is that if the law of the conservation of energy did not obtain completely in these experiments the variations from it have been far too small to bear any comparison with the total energy transformed; and making all allowance for errors, etc., the experiments may be fairly said to demonstrate that the law of the conservation of energy held good as regards the men who were studied. For practical purposes we are, therefore, warranted in assuming that the law obtains in general, as indeed there is every reason *a priori* to believe that it must obtain in the living organism.

THE DEMANDS OF THE BODY FOR NOURISHMENT AND DIETARY STANDARDS.

BY W. O. ATWATER.

EXPERIMENTS WITH MEN IN THE RESPIRATION CALORIMETER.

One of the objects of experiments with the respiration calorimeter is to obtain exact information regarding the demands of the body for food, with different persons and under different conditions of rest and work. Data bearing upon these questions are found in all of the experiments. The detailed tables elsewhere published* show the total amounts and the composition of the food, drink, and excretory products. The figures in Table 20 summarize very briefly some of the principal results.

By "digested food" is understood the total food less the intestinal excreta—in other words, the sum of the nutrients which are available to the body for the building of tissue and yielding of energy, and are hence called "available nutrients." No correction is introduced for metabolic products in the feces, since these were derived originally from the food (or body tissue) and are a necessary accompaniment of undigested material. The available energy of the food is the total heat of combustion of the food minus the heat of combustion of the unoxidized materials of feces and urine. No further correction for the labor of chewing and digesting is included.†

It is here assumed that the quantity of carbohydrates in the body is the same at the beginning as at the end of the experiment. The gains and losses of body protein and body fat are computed from the gains and losses of the nitrogen and carbon.‡ Accordingly the figures show the average daily amounts of available protein and energy supplied by the food and the

* U. S. Dept. Agr., Office of Experiment Stations, Buls. 44, 63, 69, 109 and 136.

† See discussion of this subject in articles on "The Terms Digestibility, Availability and Fuel Value" and "Availability and Fuel Value of Food Materials" in the Connecticut (Storrs) Station Rept., 1899, pp. 69 and 73.

‡ By the method previously described, U. S. Dept. Agr., Office of Experiment Stations, Bul. 69, pp. 44, 45.

TABLE 20.

Average daily income and outgo of material and energy, and gains or losses of protein and fat, in metabolism experiments Nos. 1–55.

SUBJECT, DURATION AND KIND OF EXPERIMENTS.	Nitrogen.	Carbon.	Energy.	Protein.	Fat.
Rest Experiments.	Grams.	Grams.	Calories	Grams.	Grams.
E. O., 15 experiments, 46 days:					
In digested food, - - -	17.6	232.4	2,475	110.0	—
In materials oxidized, - -	18.1	217.7	2,293	113.1	—
Gain (+) or loss (—) in body,	—.5	+14.7	—	—3.1	+21.2
O. F. T., 1 experiment, 5 days:					
In digested food, - - -	14.4	216.5	2,442	90.0	—
In materials oxidized, - -	13.7	219.9	2,505	85.6	—
Gain (+) or loss (—) in body,	+.7	—3.4	—	+4.4	—7.3
A. W. S., 6 experiments, 15 days:					
In digested food, - - -	14.6	221.8	2,424	91.3	—
In materials oxidized, - -	14.2	222.9	2,446	88.8	—
Gain (+) or loss (—) in body,	+.4	—1.1	—	+2.5	—3.2
J. F. S., 4 experiments, 12 days:					
In digested food, - - -	15.2	223.7	2,352	95.0	—
In materials oxidized, - -	15.7	205.4	2,119	98.1	—
Gain (+) or loss (—) in body,	—.5	+18.3	—	—3.1	+26.2
J. C. W., 1 experiment, 4 days:					
In digested food, - - -	14.8	214.3	2,274	92.5	—
In materials oxidized, - -	15.8	221.5	2,357	98.8	—
Gain (+) or loss (—) in body,	—1.0	—7.2	—	—6.3	—5.0
E. O., O. F. T., A. W. S., J. F. S., and J. C. W., 27 expts., 82 days:					
In digested food, - - -	16.4	227.4	2,436	102.5	—
In materials oxidized, - -	16.6	217.2	2,310	103.8	—
Gain (+) or loss (—) in body,	—.2	+10.2	—	—1.3	+14.4
Work Experiments.					
E. O., 3 experiments, 12 days:					
In digested food, - - -	17.7	324.0	3,513	110.6	—
In materials oxidized, - -	17.6	354.2	3,560	110.0	—
Gain (+) or loss (—) in body,	+.1	—30.2	—	+.6	—40.4
A. W. S., 1 experiment, 3 days:					
In digested food, - - -	14.8	223.6	2,505	92.5	—
In materials oxidized, - -	14.1	371.5	4,325	88.1	—
Gain (+) or loss (—) in body,	+.7	—147.9	—	+4.4	—196.3
J. F. S., 6 experiments, 18 days:					
In digested food, - - -	15.0	302.9	3,245	93.7	—
In materials oxidized, - -	16.4	328.7	3,560	102.5	—
Gain (+) or loss (—) in body,	—1.4	—25.8	—	—8.8	—27.8
J. C. W., 14 experiments, 46 days:					
In digested food, - - -	15.4	417.2	4,416	96.3	—
In materials oxidized, - -	17.5	474.4	5,120	109.4	—
Gain (+) or loss (—) in body,	—2.1	—57.2	—	—13.1	—66.0
E. O., A. W. S., J. F. S., and J. C. W., 24 experiments, 79 days:					
In digested food, - - -	15.7	369.6	3,939	98.1	—
In materials oxidized, - -	17.2	419.0	4,547	107.5	—
Gain (+) or loss (—) in body,	—1.5	—49.4	—	—9.4	—58.4

amounts actually used by the body when the subject had a minimum amount of exercise and when he was engaged in decidedly active muscular work.

The materials actually oxidized in the body are the digested nutrients of the food minus the protein or fat gained or plus the protein or fat lost by the body. The data thus show very clearly the demands of the body under the different conditions and the increase in the demand which accompanied the performance of muscular work.

The respiration calorimeter experiments bring out very clearly the effect of muscular exercise upon the katabolism of matter and energy in the body and the consequent demand for food. Take for instance the case of one of the subjects, J. C. W., who like the others was a young, healthy, active man. When he was at rest in the calorimeter his body transformed only about 2,350 calories of energy per day. Eight hours work in driving a stationary bicycle increased this to an average of 5,120 calories. This work he did not find especially severe. It appeared that the increase of material and energy used was directly proportional to the muscular work performed. On this basis, four hours pedalling of the bicycle would have increased the transformation of energy from 2,350 to 3,735 calories. Mr. W. was a man of rather large size, a student in college, quite inclined to athletic exercise and seemed to be a reasonably liberal but not excessive eater. In the rest experiment in the chamber of the respiration calorimeter he had extremely little exercise and his body transformed only the 2,350 calories of energy just mentioned; but the moment he used his muscles for active work, the katabolism increased from a rate below that which the standards suggested beyond prescribes for a man without muscular exercise, to a rate about equal to that of the proposed standard for a "man with very hard muscular work."

These experiments simply show the quantities of material and energy metabolized by a small number of men under specific conditions of work and rest. Though their bearing upon the general subject of dietary standards can be more advantageously discussed in detail when it shall be possible to take into account not only these and other experiments with men in

the respiration calorimeter, but also a large number of experimental inquiries and observation of dietary usage of people of different classes and occupations in different countries, several interesting deductions seem warranted at the present time.

There is no doubt that in many cases the body can be maintained in nitrogen and carbon equilibrium with much smaller quantities of nitrogen and energy than those actually used by any of the men in these experiments. It is equally certain that in other cases the requirements are much larger. The tentative standards for daily diet which have been proposed by a number of investigators have served a useful purpose, but they will doubtless have to be modified as the fundamental data become more exact and numerous.

One principle which thus far has not received adequate recognition in dietary standards may perhaps be expressed by saying that the standard must vary not only with the conditions of activity and environment, but also at the nutritive plane at which the body is to be maintained. A man may live and work and maintain bodily equilibrium on either a higher or lower nitrogen level or energy level. One essential question is, What level is most advantageous? The answer to this must be sought not simply in metabolism experiments and dietary studies, but also in broader observations regarding bodily and mental efficiency and general health, strength and welfare.

These experiments show the exact quantities of materials and energy katabolized in the bodies of young, healthy, active men under different conditions of food and fasting, work and rest, and it will be interesting to summarize the results as viewed from this standpoint. This is done in Table 21.

The results summarized in the table may be considered with relation to the quantities of total food, protein and energy katabolized under the different conditions.

The quantities of total food in all the experiments except the earlier ones with E. O. and those with O. F. T. were rather small, the idea being that the body would utilize its food more economically with a limited than with an excessive supply. In the rest experiments the food was nearly or quite sufficient to maintain nitrogen and carbon equilibrium during the periods spent in the chamber of the calorimeter.

TABLE 21.

Average amounts of protein and energy katabolized daily, per person, per kilogram of body weight and per square meter of body surface, in metabolism experiments Nos. 1–55.

SUBJECT, NUMBER AND KIND OF EXPERIMENTS.	Duration.	Energy of external muscular work.	In Material Oxidized.					
			Per person.		Per kilogram of body wght.		Per sq. meter of body surface.	
			Protein. (N. × 6.25)	Energy.	Protein. (N. × 6.25)	Energy.	Protein. (N. × 6.25)	Energy.
Rest. Fasting.	D.	Cal.	Gms.	Cal.	Gm.	Cal.	Gm.	Cal.
J. C. W., 4 experiments, - -	5	—	82.0	2,250	1.08	29.6	37.1	1,018
Rest. Food generally sufficient for maintenance.								
E. O., 15 experiments, - -	46	—	113.1	2,293	1.62	32.8	54.1	1,097
O. F. T., 1 experiment, - -	5	—	85.6	2,505	1.43	41.7	45.3	1,325
A. W. S., 6 experiments, - -	15	—	88.8	2,446	1.27	34.9	49.3	1,065
J. F. S., 4 experiments, - -	12	—	98.1	2,119	1.51	32.6	49.3	1,065
J. C. W., 1 experiment, - -	4	—	98.8	2,357	1.30	31.0	44.7	1,067
Av. 27 expts. with 5 subjects, -	**82**	—	**103.8**	**2,310**	**1.51**	**33.5**	**50.1**	**1,116**
Work 8 hours. Food generally not quite sufficient for maintenance.								
E. O., 3 experiments, - -	12	214	110.0	3,892	1.57	55.6	52.6	1,863
J. F. S., 6 experiments, - -	18	233	102.5	3,560	1.58	54.8	51.5	1,789
J. C. W., 14 experiments, - -	46	546	109.4	5,120	1.44	67.8	49.5	2,317
Av. 24 expts. with 3 subjects, -	**76**	**419**	**108.1**	**4,556**	**1.49**	**62.9**	**50.5**	**2,129**
Work 16 hours. Food insufficient for maintenance.								
J. C. W., 1 experiment, - -	1	1,482	114.4	9,981	1.51	131.3	51.8	4,526

In the work experiments the supply was generally not quite sufficient for maintenance and in some of the experiments, especially those with J. C. W., it fell considerably short of meeting the demand. The drafts upon body material as shown in Table 21 above indicate the extent to which the actual demand exceeded the supply in the food.

The supply of protein in the earlier experiments with E. O. and O. F. T., and indeed in the rest experiments with A. W. S. and J. C. W. also, was intended to approach more or less nearly to the quantity to which the subjects were ordinarily accustomed, though in every case it was intended to be small rather

than large. The period of the preliminary digestion experiment which preceded the metabolism experiment was depended upon to bring the body into approximate nitrogen equilibrium in the rest experiments and in some of the earlier work experiments. In the later work experiments, especially those with J. C. W., the quantity of protein was intended to be a little less than needed for nitrogen equilibrium. The reason for making the supply of protein rather small is found in one of the purposes of the experiments, which was to compare the relative efficiency of the non-nitrogenous materials of the ration. It was thought that the action of these latter might perhaps be partially obscured with an abundant supply of protein. It was with this same general idea that the whole food supply was made small rather than large. Considering that the body has a well proven power of adapting the output of nitrogen to the income, within wide limits, it is evident that the quantities of protein katabolized in these experiments cannot be taken as an exact measure of the normal permanent demand of these subjects for protein in the daily food. Still less can the quantities be taken as the measure of the average permanent demand for men in general with corresponding muscular activity.

The case with the supply and consumption of energy is somewhat but not wholly similar. The supply was nearly or quite sufficient in the rest experiments; but in the work experiments, especially those with J. C. W., it was so small that the body made considerable drafts upon its reserve store of both non-nitrogenous and nitrogenous compounds. How much of the loss of body protein is to be ascribed to the lack of protein and how much to the lack of total energy in the diet it is impossible to say. Special experiments with different quantities of both protein and energy would be required to settle this question.

As regards the energy, however, the case is perhaps less obscure. It is safe to say that the body requires a given amount of total energy for maintenance and the production of a given amount of muscular work and that this demand varies more or less with the amount of muscular activity. It is also fair to assume that when the energy of the food does not meet its needs, it will draw upon such reserve materials as it can most conveniently utilize. The general testimony of metabolism

experiments is to the effect that the principal draft will be upon the non-nitrogenous materials as long as these last or until their quantity is so reduced that the body cannot well avail itself of more. Accordingly in these experiments, where the energy of the food is deficient, the body loses some protein but more fat.

THE NORMAL, PERMANENT DEMAND.

The question now arises: Can the quantities of energy katabolized in these experiments be taken as the measure of the normal, permanent demand of these men for equivalent muscular activity? This involves the question of the extent to which the body can adapt its consumption of energy to the supply in the food, the muscular activity remaining the same. It has such a power of adaptation for protein, though just what are the circumstances under which it can exercise this adaptive power and to what extent and for how long time it can do so, the information now available does not tell us. It would seem, however, that there must be a more nearly constant ratio between muscular activity and the katabolism of energy than between such activity and the katabolism of protein. Nor would this hypothesis conflict with the theory that the normal and permanent demand for protein varies with the intensity of the muscular activity.*

If the above reasoning be correct—and this is not wholly certain—the amounts of energy katabolized in the experiments here reported may be taken as at least approximate indications of the normal and permanent requirements of these men for corresponding grades of activity.

In short it would seem probable that the quantities of protein katabolized in these experiments are rather small, and the quantities of energy more nearly equivalent to those that would be permanently required by the same men for normal nutrition under the conditions of work and rest similar to those of the experiments. But a great deal more experimenting will be needed for proof that such is the case.

The bearing upon dietary standards of these respiration calorimeter experiments in which the diet was planned to meet the needs of the body and its efficiency for this purpose was

*See Zuntz, U. S. Department of Agriculture, Experiment Station Record, Vol. VII., p. 538.

actually measured, is obvious and will be considered, but first it may be well to consider briefly what is meant by a dietary standard and its relation to dietary studies—or in other words to the kind of research which in the past has been most commonly followed to secure facts for calculating the standards.

In this connection it should be remembered, however, that the standards which have been most generally accepted do not depend wholly upon dietary studies, or in other words upon the amounts which persons of different age, sex and occupation are found to eat, but upon physiological studies as well.

DIETARIES OF PEOPLE OF DIFFERENT CLASSES AND OCCUPATIONS IN DIFFERENT COUNTRIES.

Much information regarding the kinds, amounts and nutritive values of the food of people of different age, sex, occupation, income and surroundings in different parts of the world has accumulated during the past twenty years. This comes from studies of actual dietaries in England, Germany, Italy, Russia, Sweden and elsewhere in Europe, and in Japan and other Oriental countries. Within the past dozen years extensive studies of this kind have been made in the United States. The Storrs Experiment Station has been one of the pioneers in this kind of inquiry and accounts of a considerable number of its dietary studies have appeared in its annual report.

The common way of making such studies is to find what kinds and quantities of food are used during a given period, as a week or a month, in the household or other establishment where the study is made; to find the amounts of nutrients in the food, either by analysis or by use of figures for the average composition of the various food materials;* noting the number of persons who are nourished by the food and the number of meals eaten by each and then calculating the amounts of nutrients per person per day.

There are, however, several chances for error in such a method. In the first place, since different specimens of the same kind of food vary greatly in composition, it is often inaccurate to estimate the nutrients of one specimen from figures representing the average composition. Accordingly, in the more

* Such as have been given in previous reports of this Station and in Bulletin 28 of the Office of Experiment Stations of the U. S. Department of Agriculture.

careful dietary studies, the composition of the food is determined by analyzing samples of materials actually used. Again, this method assumes that all the food is really consumed, whereas it is very plain that frequently no small portion is wasted in the kitchen or at the table. The difficulty is usually met in the later American studies, by measuring and computing the amounts of nutrients in the waste and sometimes by analyzing samples of it.

In preparing the results of dietary studies so that different studies may be compared, another difficulty appears. For example, in a family consisting of father, mother, and two children of different ages the amount of food taken by each is by no means the same, and it would be quite incorrect to divide the whole amounts consumed by four and call the result the amount used per person. Men, as a rule, eat more than women, women more than young children, and persons of active habits more than those who take little muscular exercise. A coal heaver, who is constantly using up nutritive material or muscular tissue to supply the energy required for his severe muscular work, needs a diet with more protein and higher fuel value than a bookkeeper who sits at a desk all day. It is ordinarily estimated that, as compared with a man at moderate or light work, a woman under similar conditions needs 0.8 as much food, and children amounts that vary with their ages, and such figures are used to reduce the statistics of a dietary to the standard of one man at moderate work. The various factors commonly used in the United States in computing the results of dietary studies are as follows:

FACTORS USED IN CALCULATING MEALS CONSUMED IN DIETARY STUDIES.

Man at hard muscular work requires 1.2 the food of a man at moderately active muscular work.

Man with light muscular work and boy 15–16 years old require 0.9 the food of a man at moderately active muscular work.

Man at sedentary occupation, woman at moderately active work, boy 13–14, and girl 15–16 years old require 0.8 the food of a man at moderately active muscular work.

Woman at light work, boy 12, and girl 13–14 years old require 0.7 the food of a man at moderately active muscular work.

Boy 10–11 and girl 10–12 years old require 0.6 the food of a man at moderately active muscular work.

Child 6–9 years old requires 0.5 the food of a man at moderately active muscular work.

Child 2–5 years old requires 0.4 the food of a man at moderately active muscular work.

Child under 2 years old requires 0.3 the food of a man at moderately active muscular work.

These factors are based in part upon experimental data and in part upon arbitrary assumptions. They are subject to revision when experimental evidence shall warrant more definite conclusions.

In making dietary studies in this country blanks are usually prepared to be filled out with statistics of the amounts, kinds, cost, and estimated nutrients of the food purchased, wasted, and actually consumed, and information concerning the number, sex, age, and occupation of the persons for whom the food is provided. If further data are gathered concerning the health, nationality, income and general conditions of the individuals of families, the results of such inquiries have a wider physiological and sociological bearing. These supplementary statistics have been collected in considerable detail in late studies in the United States.

Within a short time past a considerable number of dietary studies have been made in Great Britain by use of the schedules now commonly employed in the United States. These schedules, which are the outcome of considerable experience, are prepared by the U. S. Department of Agriculture for use by those who coöperate with that Department in nutrition investigations in different parts of the country. It is to be hoped that this coöperation, which has been so well developed in our own country and is already extending outside, may be still further increased, because a large number of observations of such sort as to be easily compared one with another are the best possible means for learning some of the most important facts which bear upon the nutrition of man. Awaiting such detailed, accurate and comparable information, we may make use of the information which has already accumulated and is of very great interest.

Many interesting things come to light on comparing the dietaries of persons with different occupations and incomes and performing different amounts of muscular work. A comparison of the dietaries of the inhabitants of different countries

is also interesting. Such comparisons are made in the following table, which includes also the very exact values obtained when the experimental conditions were carefully controlled and data were collected regarding the use the body made of the food in experiments in which respiration apparatus was used. Appended to the table are the commonly accepted dietary standards.

The figures given for fuel value may be computed from either the total or the digestible nutrients by use of appropriate factors.* The nutritive ratio in each case is calculated by multiplying the weights of the fats by two and one-quarter, adding the weight of the carbohydrates and dividing by the weight of the protein. The reason for multiplying the fats by two and one-quarter is that a gram of fat has two and one-quarter times the energy of fuel value of a gram of carbohydrates. Since the available energy of a gram of protein is practically equal to that of a gram of carbohydrates the nutritive ratio of a given food material or a given dietary is practically the ratio of the available energy of the protein to that of the carbohydrates and fats together.

DIETARY STANDARDS.

Fortunately the subject of the demand of the body for nourishment is receiving unusual attention of late from physiologists, physicians, economists and teachers and it may not be unfitting to urge once more the importance of the principles enunciated above.

The later technical discussion of this subject turns largely upon the quantities of protein and energy required for the normal nourishment. Several European investigators have proposed so-called dietary standards, which agree more or less closely with each other. Of the European standards the best known are those of Voit, which are given in Table 22, together with several suggested by myself.†

A dietary standard is in brief, a formula which attempts to express the physiological demand for nourishment in terms of nutrients, or better in terms of protein and energy. The quantities of these actually required by a given person vary with

*These factors are as follows: For each gram of total nutrients, protein 4.0, fat 8.9, and carbohydrates 4.0 calories. For each gram of digestible nutrients, protein 4.4, fat 9.4, and carbohydrates 4.1 calories. See Storrs Station Report, 1899, p. 104.

†See U. S. Dept. Agr., Office of Experiment Stations, Bul. 21, page 206, and Farmers' Bulletin 142, p. 34.

TABLE 22.

Summary of results of dietary studies, and dietary standards.

	No. studies in avgs.	Actually Eaten. Protein.	Actually Eaten. Fat.	Actually Eaten. Carbohydrates.	Digestible Protein.	Digestible Fat.	Digestible Carbohydrates.	Fuel value.	Nutritive ratio.
PERSONS WITH ACTIVE OR HARD MUSCULAR WORK.		Gm	Gm	Gm	Gm	Gm	Gm	Cal.	1:
Workingmen, etc.									
Builders, N. Y. City, - - - -	3	195	256	718	179	242	696	5,930	6.6
Longshoreman,* N. Y. City, - -	1	212	334	888	195	317	861	7,375	7.7
Gripman,* N. Y. City, - - -	1	171	171	460	157	162	446	4,045	4.9
Family at mission, N. Y. City, - -	1	143	205	545	132	195	529	4,575	7.0
Blacksmiths, Lowell, Mass.,* - -	1	200	304	795	184	289	771	6,685	8.6
Machinist, Boston, Mass.,* - -	1	182	254	617	167	241	598	5,455	6.5
Boiler tender, Pittsburg, Pa., - -	1	147	173	683	135	164	662	4,860	7.3
Italian contract laborers, - - -	1	150	94	683	138	89	662	4,170	6.0
Russian Jew laborers, United States,	2	173	129	638	159	123	619	4,390	5.3
French Canadian brickmaker,* - -	1	132	236	750	121	224	728	5,630	8.7
Bohemian laborers, - - - - -	4	170	176	503	156	167	488	4,260	5.3
Prussian machinists (Krupp Works), -	1	139	113	677	128	107	657	4,270	6.7
Swedish mechanics, - - - - -	1	189	110	714	174	104	693	4,590	5.1
Bavarian brewery laborers, - -	5	149	61	755	137	58	728	4,160	6.0
Prussian miners, - - - - -	1	133	113	634	122	107	615	4,075	6.7
Bavarian lumbermen, - - - -	3	130	292	724	120	277	702	5,935	10.4
Bavarian farm laborers, - - -	3	137	202	546	126	192	530	4,530	7.3
Austrian farm laborers, - - -	1	159	62	977	146	59	948	5,095	7.0
Russian dock laborers, - - -	1	218	95	931	201	90	903	5,440	5.2
Average of above studies, - -	**34**	**165**	**178**	**697**	**152**	**169**	**676**	**5,030**	**6.6**
French Canadians, New England,* -	7	123	209	529	113	199	513	4,470	8.1
Shoemakers, Rostock, - - -	1	108	77	523	99	73	507	3,210	6.4
German mechanics, - - - - -	2	134	61	412	123	58	400	2,725	4.1
Swedish mechanics, - - - - -	6	134	70	523	123	66	507	3,250	5.1
Bavarian mechanics,† - - - -	12	127	51	532	117	48	516	3,090	5.1
Russian operatives,† - - - - -	59	119	65	536	109	62	520	3,200	5.7
Average above studies, - - -	**126**	**119**	**112**	**472**	**109**	**106**	**458**	**3,360**	**6.1**
Unskilled laborers.									
Truckmen, etc., N. Y. City, - -	7	108	117	362	99	111	351	2,920	5.8
French Canadian laborers,* - -	13	108	106	526	99	101	510	3,480	7.1
Foreign laborers, Chicago, - -	12	122	97	354	112	92	343	2,770	4.7
Bavarian farm laborers, - - -	5	137	55	542	126	52	526	3,205	4.8
Mexican laborers, - - - - -	1	98	65	561	90	62	544	3,215	7.2
Negro laborers, - - - - -	4	98	207	512	90	197	497	4,280	9.9
Average above studies, - - -	**42**	**112**	**108**	**476**	**103**	**103**	**462**	**3,315**	**6.4**
Professional and business men.									
Lawyers, teachers, etc., United States,	18	117	126	427	108	120	414	3,300	6.1
English Royal engineers, - - -	1	144	83	631	132	79	612	3,840	5.7
Danish physicians and teachers, -	2	127	137	263	117	130	255	2,780	4.5
German professional men, - -	8	110	102	269	101	97	261	2,425	4.5

* Food purchased. † An approximate estimate.

TABLE 22.—(*Continued.*)

	No. studies in avgs.	Actually Eaten. Protein.	Actually Eaten. Fat.	Actually Eaten. Carbohydrates.	Digestible Protein.	Digestible Fat.	Digestible Carbohydrates.	Fuel value.	Nutritive ratio.
Professional and business men.		Gm	Gm	Gm	Gm	Gm	Gm	Cal.	1:
French physician, - - - - -	1	92	61	235	85	58	228	1,850	4.0
Japanese professor, - - - - -	1	123	21	416	113	20	404	2,345	3.8
Russian Jew teacher, etc., in Chicago,	2	159	90	450	146	85	436	3,235	4.1
Bohemian druggist, etc., in Chicago, -	4	211	210	478	194	200	464	4,625	4.5
College clubs, men, in United States, -	17	107	148	464	98	141	450	3,600	7.4
College clubs, women, in United States,	7	114	141	459	105	134	445	3,545	6.8
Swedish medical students, - - -	1	127	114	300	117	108	291	2,725	4.4
Japanese students, - - - -	2	119	25	586	109	24	568	3,045	5.4
Average above studies, - - -	**64**	**129**	**105**	**415**	**119**	**100**	**403**	**3,110**	**5.0**
Dietary with minimum protein, - -	—	92	61	235	85	58	228	1,850	4.0
Dietary with maximum protein, - -	—	211	210	478	194	200	464	4,625	4.5
Dietary with minimum energy, - -	—	92	61	235	85	58	228	1,850	4.0
Dietary with maximum energy, - -	—	211	210	478	194	200	464	4,625	4.5
Average of all studies of persons with light to moderate muscular work, -	—	**122**	**108**	**449**	**112**	**103**	**436**	**3,245**	**5.6**
Athletes.									
Harvard University boat crew, 1898, -	2	161	173	448	148	164	435	3,975	5.2
Harvard Freshman boat crew, 1898, -	2	145	188	442	133	179	429	4,020	5.9
Captain Harvard Freshman boat crew,'98	1	155	181	487	143	172	472	4,180	5.7
Yale University boat crew, 1898, -	2	158	171	441	145	162	428	3,920	5.2
Harvard University boat crew, 1900, -	1	154	159	473	142	151	459	3,835	5.2
College foot-ball teams (Conn. and Cal.),	2	226	354	633	208	336	614	6,585	6.3
Bicycle racers, New York City, - -	4	182	178	582	167	169	565	4,640	5.4
Professional "strong man" (Sandow),	1	244	151	502	224	143	487	4,330	3.4
Professional walker (Weston), - -	7	213	128	518	196	122	502	4,065	3.8
Canoeing party in Maine,* - - -	1	172	261	533	158	248	517	5,145	6.5
Average of above studies, - -	**23**	**181**	**194**	**506**	**167**	**184**	**491**	**4,475**	**5.2**
Dietary with mimimum protein, - -	—	130	292	724	120	277	702	5,935	10.4
Dietary with maximum protein, - -	—	244	151	502	224	143	487	4,330	3.4
Dietary with minimum energy, - -	—	154	159	473	142	151	459	3,875	5.2
Dietary with maximum energy, - -	—	212	334	888	195	317	861	7,375	7.7
Average of all studies of persons with active or hard muscular work, -	**57**	**170**	**184**	**631**	**156**	**175**	**612**	**4,840**	**6.1**
PERSONS WITH LIGHT TO MODERATE MUSCULAR WORK.									
Farmers.									
Farmers, Connecticut, - - -	7	102	126	470	94	120	456	3,410	7.4
Farmers, Vermont, - - - - -	5	98	148	482	90	141	468	3,635	8.3
Farmers, New York, - - - - -	2	123	133	527	113	126	511	3,785	6.7
Farmers, av. eastern U. S., - - -	14	108	136	493	99	129	478	3,615	7.4
Mexican farmers, - - - - -	3	97	69	608	89	66	590	3,435	7.9
Russian peasants, - - - - -	?	129	33	589	119	31	571	3,165	5.1
Italian peasants, - - - - - -	2	118	65	628	109	62	609	3,565	6.6
Average above studies, - - -	**20**	**111**	**96**	**551**	**102**	**91**	**534**	**3,500**	**6.9**

* Food purchased.

TABLE 22.—*(Continued.)*

	No. studies in avgs.	Actually Eaten.			Digestible			Fuel value.	Nutritive ratio.
		Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
Mechanics, Operatives, Etc.		Gm	Gm	Gm	Gm	Gm	Gm	Cal.	1:
Factory operatives, Mass.,*	6	118	173	523	109	164	507	4,105	7.7
Mechanics, Conn.,	8	106	146	393	98	139	381	3,295	6.8
Mechanics, New York City,	12	119	117	407	109	111	395	3,145	5.6
Mechanics, United States,	4	107	151	421	98	143	408	3,455	7.1
Foreign mechanics in Chicago,	9	115	107	388	106	102	376	2,965	5.4
Persons with little or no muscular exercise.									
Men (American) in respiration apparatus,	32	107	141	445	97	135	435	3,510	7.2
Men (German) in respiration apparatus,	5	127	80	302	117	76	293	2,430	3.8
Inactive male patients, N. Y. hos. insane,	26	80	78	367	74	74	356	2,480	6.7
Inactive female patients, N. Y. hos. insane	22	64	74	294	59	70	285	2,110	7.2
Patients, Conn. hospital for insane,	3	84	100	356	77	95	345	2,650	6.9
German prisoners without work,	1	98	28	440	90	27	427	2,400	5.1
Inmates German home for old women,†	1	80	49	266	74	47	258	1,820	4.7
Inmates Ger. home for old men & women†	1	92	45	332	85	43	322	2,095	4.7
Japanese prisoners without work,†	1	48	7	372	44	7	361	1,740	8.1
Persons in destitute circumstances.									
Poor families in New York City,*	10	79	80	316	73	76	307	2,290	6.2
Poor families in Pittsburg,	3	85	104	334	78	99	324	2,600	6.6
Poor families, unclassified,	5	112	104	511	103	99	496	3,420	6.6
Dietaries of children.									
Infants—ages not given,	4	17	34	63	16	32	611	625	8.2
Children, 6 months to 1 year old,	2	67	63	158	62	60	153	1,450	4.4
Children, 1 year to 2 years old,	1	97	93	367	89	88	356	2,685	5.9
Children, 2 years to 5 years old,	1	75	50	300	69	48	291	1,945	5.5
Miscellaneous.									
Man, unusually thorough mastication,	1	39	—	—	—	—	—	1,260	—
Fruitarians in California,	6	50	97	236	46	92	229	2,005	9.0
German vegetarian,	1	74	58	490	68	55	475	2,770	8.4
Inhabitants Java village, Col. Expos.,'93	1	66	19	254	61	18	246	1,450	4.5
Families in "poor" quarter, N. Y. City,	53	93	101	362	86	96	351	2,720	6.3
Families in "poor" quarter, Phila.,	25	109	108	435	100	103	422	3,135	6.2
French Canadians in Chicago,	5	108	150	325	99	143	315	3,065	6.1
Italians in Chicago,	4	100	103	400	92	98	388	2,915	6.3
Bohemians in Chicago,	25	139	129	418	128	123	405	3,375	5.1
Russian Jews (orthodox) in Chicago,	11	122	89	420	112	85	407	2,960	5.1
Russian Jews (unorthodox) in Chicago,	5	144	91	392	132	86	380	2,955	4.1
Japanese clerks,	—	55	6	394	51	6	382	1,850	7.4
Chinese dentist, California,	1	115	113	289	106	107	280	2,620	4.7
Chinese laundrymen, California,	1	135	76	566	124	72	549	3,480	5.4
Chinese farm laborers, California,	1	144	95	640	132	90	621	3,980	5.9
Mexicans in New Mexico,	4	94	71	613	86	67	595	3,460	8.2
Negroes in Virginia,	19	107	157	435	98	149	422	3,565	7.3
Negroes in Alabama,*	20	62	132	436	57	125	423	3,165	11.8

* Food purchased. † Per person per day.

TABLE 22.—(*Continued.*)

	No. studies in avgs.	Actually Eaten.			Digestible			Fuel value.	Nutritive ratio.
		Protein.	Fat.	Carbohydrates.	Protein.	Fat.	Carbohydrates.		
Miscellaneous.		Gm	Gm	Gm	Gm	Gm	Gm	Cal.	1:
Prisoners at work (English),	1	131	39	525	121	37	509	2,970	4.7
Prisoners at hard work (English),	1	151	43	622	139	41	603	3,475	4.8
Prisoners at work (German),*	2	115	34	580	106	32	563	3,085	5.7
Prisoners at work (Japanese),	2	66	9	544	61	9	528	2,520	8.5
Attendants in insane asylums (U. S.),	6	85	132	352	78	125	341	2,925	7.6
United States Army ration, peace footing	—	120	161	454	110	153	440	3,730	6.8
United States Navy ration, peace footing	—	143	183	520	132	174	504	4,280	6.5
German Army ration, peace footing,	—	114	39	480	105	37	466	2,725	5.0
German Army ration, war footing,	—	134	58	489	123	55	474	3,010	4.6
German Army rat., ex'ordinary war foot'g	—	192	45	678	177	43	658	3,880	3.9
German Army rat., extra., Fr.-Ger. war,	—	157	285	331	144	271	321	4,490	6.1
Italian Army ration, peace footing,	—	114	14	592	105	13	574	2,950	5.5
Dietary standards.									
Man, hard work (Voit),	—	145	100	450	133	95	437	3,270	4.9
Man, moderate work (Voit),	—	118	56	500	109	53	485	2,965	5.5
Man, very hard muscular work (Atwater),	—	175	(1)	(1)	161	(1)	(1)	5,500	7.2
Man, hard muscular work (Atwater),	—	150	(1)	(1)	138	(1)	(1)	4,150	6.2
Man, moderately act. muscular work (A.),	—	125	(1)	(1)	115	(1)	(1)	3,400	6.2
Man, light to mod. muscular work (A.),	—	112	(1)	(1)	103	(1)	(1)	3,050	6.1
Man, sedentary, or woman, moderately active work (Atwater),	—	100	(1)	(1)	92	(1)	(1)	2,700	6.1
Woman, light to moderate muscular work or man without muscular exercise (A.),	—	90	(1)	(1)	83	(1)	(1)	2,450	6.1

(1) Fats and carbohydrates in amounts sufficient to furnish together with the protein the indicated amount of energy.

* Food served.

age, sex, occupation and especially with the individuality of the person and the mental and physical activity. The formula must include an expression of the measure of that activity. For the ordinary forms of muscular activity, no adequate measure or standard of measurement has been established. This indefiniteness is illustrated by expressions for physical activity in the standards here quoted. The term "moderate work" is used by Voit to designate such manual labor as might be performed by an average mechanic, as for instance, a carpenter or mason, working 10 hours per day, in Bavaria, where most of the observations upon which he based his standards were made. In this country people are believed to work more actively than in Europe, and in suggesting American standards it was assumed

that what might here be considered "light to moderate muscular work" would perhaps correspond to Voit's "moderate work," while "moderately active muscular work" with us might approach more nearly to what would pass in Germany as "hard work." Accordingly the standard of 112 grams of protein and 3,050 calories of energy proposed by myself would compare to about the same grade of activity as Voit's standard of 118 grams of protein and 2,965 calories of energy. The main difference between the two is that the American formula calls for a little less protein and more energy than the German. I emphasize this because the two have been compared in such ways as to imply that the standards suggested by myself call for more protein than those of Voit and other European physiologists whereas for directly comparable cases the opposite is the fact.

STANDARDS FOR PEOPLE IN PROFESSIONAL AND BUSINESS LIFE.

Special attention should be called to a misunderstanding which has frequently obtained with regard to these dietary standards. That of Voit for "a man at moderate work" and that of myself for "a man at moderately active work" are intended to apply to men engaged in normal labor. They do not show the amount of nutrients "required by an adult man under normal conditions of life" unless those conditions include considerable muscular activity. Most business and professional men and many farmers, mechanics and laborers have much less muscular exercise, taking their activity the year round, than these standards provide for. The standard of 100 grams of protein and 2,700 calories of energy in the food actually eaten was intended to approach more nearly to the average demand of men of this class. Women with the ordinary occupation of the house apparently require less food, as do also not a few men who have very little muscular exercise. An attempt to express this still smaller need is made in the standard which calls for 90 grams of total protein and 2,450 calories in the food actually eaten per day. Still smaller quantities suffice for many adults, especially the aged and infirm, and for young children.

MUSCULAR ACTIVITY AND THE DEMAND FOR NUTRIMENT.

I am here laying much stress upon muscular activity as increasing the demand for nutriment. The principle is perfectly simple and perfectly well understood. Every feeder of horses or oxen appreciates its force and applies it in his feeding practice; but most of us fail to realize that the principle is as valid for man as it is for the lower animals, and we are apt to eat what we like without much regard to our physiological needs. The case is affected in a peculiar way by a fact to which not all of us have given due consideration. Generally speaking smaller incomes go with manual and larger with mental labor. In other words the well-to-do not only have all they want to eat but their food is apt to be such as to tempt the appetite, so that while they really need less food than their neighbors with less money and harder manual work, they are unconsciously led to eat as much or more.

INDIVIDUALITY, HABIT AND MUSCULAR ACTIVITY.

Comparison of the results of dietary studies and metabolism experiments, including those with the respiration apparatus and the respiration calorimeter, has led me to believe that the actual needs of the body are more largely affected by the three factors, habit, the personality of the individual and the degree of muscular activity, than has always been appreciated, and I have in previous discussions of the subject felt it important to insist upon three things:

First; that no standard for a given class can be more than the expression of an average demand, from which the needs of individual persons of the class may vary widely.

Second; that the data now at hand do not suffice for at all accurate statements of the average demand for any given class. The current standards are therefore, at best, tentative, more or less crude, and subject to revision as data accumulate.

Third; that the facts at hand suffice to warrant the belief that for many if not most people with sedentary and intellectual occupations as distinguished from active muscular labor, comparatively small amounts of food are sufficient and more healthful than such quantities as are needed by manual laborers, and are actually eaten by many people not engaged in manual work.

This last statement applies especially to professional and business men and to women. It is a common belief of physiologists and physicians that many of us do great injury to our health by the unwitting use of one-sided and excessive diet. Although the data needed for exact measurement of this evil are lacking, the indications that it exists are certainly very strong.

THE DEMAND FOR PROTEIN.

A large number of more or less exact investigations have lately accumulated which show statistically what has long been known from more general observation, namely, that many people live in health and comfort, and some do considerable amounts of work, with food supplying less energy and much less protein than current standards call for. The question is often and pertinently asked: Are not these standards too liberal? Does not following them result in damage to health and loss to purse? With our present lack of detailed information it would seem that an affirmative answer would be safer for people whose work is with their brains than for those who work with their hands. Personally I should not feel free to give this answer for either class without stronger warrant from actual experience than is now in sight.

Undoubtedly some people can get on well with only half or even less than half of the protein the standards call for. A considerable number of well attested cases of this sort have been found during the past few years, several of them, indeed, in the nutrition investigations under my charge. In some cases men with more or less muscular activity have maintained nitrogen equilibrium for a number of days of actual tests with a diet supplying not far from 7 grams of nitrogen or 44 grams of protein per day, and in some instances this diet apparently represented their usual food consumption. But the tests were not long enough to show what were the amounts of nutrients in their food month after month or year after year, nor was there anything in the observations to indicate the permanent effect of such a diet upon health, strength and bodily welfare.

There are likewise numerous instances where people have much less energy in their daily food than the standards provide; but here again the data are insufficient to show just what

amounts are best for an average individual of a given class. Such data as I have been able to gather seem to me now to favor the common belief that the need of protein in the diet increases with the intensity as well as the total amount of muscular, if not mental, work, and nothing could be clearer than the testimony both of common experience and of the experiments here reported, regarding the increase of metabolism of material and energy in the body with increase of muscular activity.

It will not be out of place here to give a word of warning regarding the not uncommon practice of basing general theories of nutrition upon the results of special experience. There are abundant instances of people eating very large quantities of food without excessive muscular exercise and maintaining health and strength for many years. No less common are the cases in which "very small eaters" maintain a high degree of physical and mental activity and the best of health until old age. But it would be hardly justifiable to take the experience of either the one class or the other as a measure for a general dietary standard.

ESTABLISHING OF DIETARY STANDARDS. INQUIRY NEEDED.

The establishment of dietary standards is not a simple matter. If, for instance, we endeavor to formulate quantities of protein and energy appropriate for a man with a small, medium or large amount of muscular work, not only do we lack the exact measure of the activity, but no data to show either the range of variation or the average actual demand for any given grade of activity are available. We can do simply what has been done by numerous investigators, observe the kinds and amounts of food that are actually eaten by people whom we regard as well nourished, compare the results with those of more or less exact feeding experiments, metabolism experiments and others, with persons having different amounts of food under different conditions of work and rest, and then content ourselves with such general estimates as seem to have the highest grade of probability in their favor. But no one knows how nearly correct they are for people of a given class or how close they come to the measure of the actual needs of any given individual of that class.

This is not meant to decry dietary standards. It is simply a call for more exact information on which to base them. That information must be obtained in the ways in which the knowledge we now have has been gathered, only the methods of inquiry must be more thorough and the range more extensive. The importance of this subject from the hygienic, economic and sociological standpoints is such as to call for much more thorough study than has thus far been devoted to it.

Such studies should include:

1. Metabolism experiments. These are usually made with one or at most a very few persons, and during periods of a few days. The determinations commonly made are amounts and composition of food, feces and urine and changes of body weight. Such experiments are valuable but they do not show the gains and losses of body material other than nitrogen. To determine the gains and losses of fats, carbohydrates and water the respiration apparatus or better the respiration calorimeter is needed.

One defect of metabolism experiments thus far is that they have not been continued long enough with the same individuals and have not been repeated with large enough numbers of different individuals. This might be done even in respiration calorimeter experiments by having persons regularly employed as subjects by the year. The amounts and composition of food, feces and urine and changes in body weight could be determined continuously and the subjects could enter the calorimeter chamber at regular intervals for experiments of a few days each which would indicate more clearly the total change of body material under the given regimen of diet and occupation, which should be as nearly constant as practicable during the whole time. Observations of health, strength, working power and general well being could be made. The tests could be repeated from year to year with the same and different individuals and thus data of value would gradually accumulate.

It must be remembered that physiological experiments of short duration and with few persons do not show what is the effect of a given diet, on the long run, upon people generally. The information really needed is the permanent effect of diet upon health, physical and mental productive power and general

welfare. Part of this larger information may be had from metabolism experiments. For the rest we must go outside of the respiration apparatus and outside of the laboratory and make the observations on a larger scale with people under the usual conditions of life.

2. Special feeding experiments with individuals and with groups of people under ordinary conditions. These should be planned for the study of specific questions and continued through long periods, months or years. Those with groups can be made where large numbers of people eat together, as in boarding houses, charitable and penal institutions, and the army and navy. Such experiments have been carried on with success, and more are greatly needed.

3. Dietary studies. Another way of getting the larger knowledge is by studies of the amounts and composition of food eaten by people in ordinary conditions of life. The observations should include not only the character and cost of diet but housing, clothing, occupation, producing and earning capacity, health, intelligence, general scale of living and material and moral welfare. In this way much has been learned and far more can be learned of the influence of diet as a factor of the welfare of the individual, the family, and the community at large.

Such observations need to be made not only with people of different classes and conditions of life in this country but in other countries also. Rightly carried out they would amount, indeed, to the study of the comparative nutrition of mankind. I venture to suggest that the time is ripening, if not already ripe, for coöperative inquiry of this kind in different parts of the world.

As a means of promoting such inquiry as well as an aid to the utilizing of the results already obtained, an important need is a compilation of the results of investigations of the character and composition of food materials, dietary studies, digestion experiments and metabolism experiments already made in different countries. This is a task of considerable magnitude, but a beginning has been made in connection with the nutrition investigations of which the metabolism experiments here reported form a part, and it is hoped that the enterprise may be gradually pushed to reasonably successful completion.

IN HOW FAR ARE DIETARY STANDARDS TO BE FOLLOWED?

A dietary standard is an indication, not a rule. It is an attempt to express an average demand for people of a class, not a regimen for any given individual. It is at best an estimate with little claim to accuracy. And even if it be accurate for a given individual, it does not follow that that individual should regulate his diet for each day by the standard.

A dietary standard cannot be a rule because, in the first place, no physiologist to-day knows exactly what is a normal or necessary physiological demand for any class of persons, and even if future research shall suffice to show the average demand for a given class, the demand of any given individual of the class may vary from the average. The demand to-day may be different from that to-morrow or that of summer from that of winter, or that for one occupation different from that for another. On the other hand, as estimates and general indications, dietary standards are decidedly useful.

In another sense a dietary standard is not a rule, that is, it need not be followed as a daily regimen. It is not necessary that the deposits on a bank account should balance the drafts each day, but it is important that they should be nearly equal for long periods. It is not necessary that the diet for each day should exactly equal the physiological demand of the body for nutriment each day. The body is a storehouse of matter and energy. The store is being continually increased and diminished. Nature provides for large variations of income and outgo without harm. But it is important that the income should, on the long run, equal the necessary outgo. We need not count the grams of protein and calories of energy in our daily food, but we should attempt to regulate the kinds and amounts so that no large excess of food should be taken, to be either accumulated in the body or gotten rid of at the expense of health and strength, and also that there should be no long-continued deficit to drain the resources of the system.

One principle, too often forgotten, is that appetite is not necessarily the measure of the demand for nutriment. A normal appetite might be such a measure, but our appetites are not always normal. The habits of modern life, the abundance and cheapness of food, the tendency to follow the dictates of

the palate rather than of reason, the constant and successful effort to secure the foods that are most palatable, and to cook and to serve them in the most attractive way, the utilizing of the facilities of modern commerce to ransack the four quarters of the earth for things that people like to eat, and the common practice of having them on the table three times each day, the prevalence of the theory that what we want to eat is good food and enough of it, the gradual tendency of large classes of people away from manual exercise while they are beset with this manifold temptation to excessive eating—all these things combine to cultivate an abnormal appetite and to provide for its gratification without the needed restraint.

It is also a fair question whether the result of all these things has not been to induce among a large class of well-to-do people, with little muscular activity, a habit of excessive eating, which has become so fixed and natural that its existence is not recognized, but which nevertheless may be responsible for great damage to health, to say nothing of injury to the purse. These things are well worth the careful consideration of students of dietetics, of physiology, of hygiene and social economy.

Some thirty years ago it was my fortune as a student in Germany to become acquainted with the modern theory of the nutrition of animals. That theory was then just taking the shape which it has permanently assumed. German farmers were becoming familiar with the terms protein, fats, carbohydrates, and feeding standards such as those of Wolff were coming into common use. I was greatly interested to observe not only the grounds upon which the scientific experimenters based these standards but also the view in which they were held by intelligent practical farmers. The expression "an indication not a rule" which I have just applied to dietary standards is a literal translation of what such a German farmer said to me of feeding standards at that time.

Shortly after that experience it was my privilege to give a detailed explanation, so far as I know the first in the English language, of the German feeding standards, at meetings of the Maine and Connecticut Boards of Agriculture and in public prints. Since then the subject has become very familiar to experimenters, teachers, writers and many farmers in our own and other English speaking countries. The underlying

principle is thoroughly rational. People like definite statements, and feeding standards and tables of composition of feeding stuffs proved very attractive. What is more to the point, scientific experiments and practical experience showed the correctness of the theory and the practical utility of its application. In some instances the doctrine seemed almost in danger of degenerating into a fad, and I felt constrained to make a protest in the following language:

"The modern doctrine of food and nutrition as applied to the nourishment of domestic animals and man is in danger of being misapplied. Indeed, it is being misapplied to an extent already serious. * * * The evils are practically three; the failure to recognize what feeding and dietary standards are and ought to be, the setting up of incorrect standards, and the blind and thoughtless use of such standards in the calculating of rations and dietaries."

Strangely and yet perhaps not unnaturally, the practical development of the science of human nutrition has been of later and slower growth than that of the nutrition of animals. It is only within a few years past that dietary standards have been discussed very widely in English. But of late they are being studied by experimenters, taught in schools and discussed in books, magazines and newspapers until many people have become familiar with them. As is the case with the feeding standards, the principle is rational, the theory stands the test of scientific criticism and practical experience, the utility is perfectly clear, the idea is attractive to many people and it too is in some quarters becoming somewhat of a fad.

Having been one of the first to advocate the general idea in this country, I venture once more to enter a protest against the too mechanical use of the numerical expressions which are intended merely as illustrations of a physiological principle.

Tables of composition of food materials and dietary standards are rational and useful; and daily menus showing proportions of different food materials which would supply a family of a given number of persons with nutrients and energy fitted to those standards are eminently proper and serviceable as general indications of what may be a well adjusted diet. But the housewife who attempts to bring the daily meals of herself and family into exact mathematical accord with any given standard will not be making the best use of what the science of nutrition offers.

THE COMPOSITION OF POULTRY.

REPORTED BY W. O. ATWATER.

The analytical work carried on during the past year in connection with the nutrition investigations of the Storrs Station has included determinations of the chemical composition and heats of combustion of samples of a considerable number of different kinds of poultry and poultry products, for a study of the nutritive value of this class of food materials. This work was in charge of Mr. R. D. Milner, chemist of the nutrition investigations of the Station, who has also supervised the tabulation of the results and has prepared the present article reporting the study. The samples of poultry and poultry products were collected by Mr. F. E. Singleton, secretary of the Station nutrition investigations. The chemical analyses were made by Mr. E. Osterberg, and the determinations of the heats of combustion by Mr. E. M. Swett.

DESCRIPTION OF SAMPLES.

In a few instances, noted below, it was necessary to use cold storage birds for analysis; but wherever possible the poultry was purchased alive, and was killed, dressed and drawn for these studies by a local butcher. The major part of the poultry analyzed was raised in the vicinity of Middletown. None of the birds was raised or fattened especially for this investigation, but in every case care was taken to secure birds that were believed to be representative of the different classes of poultry when in good marketable condition.

In dressing the birds the feathers, feet and head were removed; in drawing them the entrails were removed, but the giblets, *i. e.*, the heart, liver, etc., which are usually utilized, were retained with the dressed and drawn carcass. The weight of the drawn poultry given in the description of samples below is that of the carcass and giblets together.

It was the intention to have the weights of the birds taken when alive, after killing and dressing, and after drawing, to get information regarding the amount of material removed in these operations; but by mistake the person who dressed the samples neglected to take most of these weights.

The birds were weighed immediately upon their receipt at the laboratory, and the bones were removed at once and weighed, care being taken that none of the flesh was lost in this operation. The flesh was then ground several times in a meat chopper. In the case of the small birds the total amount of flesh, and in some cases the flesh of two birds, was ground together; but with some of the larger birds portions of the light and dark meats were reserved for separate analysis. In all cases the giblets were ground and analyzed separate from the rest of the flesh. When the total amount of flesh was small it was all dried and finely ground for analysis; but when large, two 400-gram portions of the thoroughly mixed chopped meat were set aside for this purpose.

The samples are given in the following descriptions alphabetically, to agree with the order in Table 23.

Nos. 3609–3612. Capon. Cold storage birds from New York market. Two birds were analyzed, the total weights for both being: drawn, 4398 grams; giblets, 394 grams; bones, 769 grams.

Nos. 3557–3560, 3595–3597. Chicken. Raised in Middletown. Three chickens nearly a year old were used. In the case of two of the birds the total flesh from each carcass was ground for analysis, while the third was separated into light and dark meat and these were analyzed separately. The weights of the two former birds dressed were as follows: undrawn, 3856 grams; drawn, 3470 grams; giblets, 325 grams; bones, 674 grams. The weights of the third bird were: undrawn, 1549 grams; drawn, 1156 grams; giblets, 160 grams; bones, 201 grams. The light meat weighed 499 grams and the dark meat 255 grams.

Nos. 3668–3670. Broiler chicken. Two birds about four months old, raised in the vicinity of Middletown. The weights were as follows: drawn, 1265 grams; giblets, 129 grams; bones, 284 grams.

Nos. 3565–3573, 3602–3604. Duck. Raised in the vicinity of Middletown. Four ducks were obtained and each was analyzed separately. One duck weighed twice as much as either of the others. The weights of all four together were as follows: undrawn, 8505 grams; drawn, 6678 grams; giblets, 816 grams; bones, 1045 grams. The breast meat was removed from each bird for analysis separate from the rest of the flesh, the breast meat for the four birds weighing 958 grams, and the remainder of the flesh 3665 grams.

Nos. 3605–3608. Duckling. Cold storage birds from New York market. Two birds were analyzed separately, the weights of both together being: drawn carcass, 3406 grams; giblets, 440 grams; bones, 490 grams.

Nos. 3561–3564. Fowl. Raised in the vicinity of Middletown. Two mature birds in good condition were secured and were analyzed separately. The weights of the dressed fowl, together, were as follows: undrawn, 4082 grams; drawn, 3402 grams; giblets, 281 grams; bones, 545 grams.

Nos. 3551–3552, 3555–3556. Goose. Raised in the vicinity of Middletown. Two geese were obtained, medium sized birds about two years old, and these were analyzed separately. The weights of the two dressed geese together were as follows: undrawn, 7938 grams; drawn, 7285 grams; giblets, 786 grams; bones, 807 grams.

Nos. 3551, 3553, 3554. Green goose. Raised in the vicinity of Middletown. Two birds six to eight months old. The weights of both together were as follows: undrawn, 9526 grams; drawn, 8396 grams; giblets, 812 grams; bones, 756 grams.

Nos. 3577–3580. Guinea hen. Raised in the vicinity of Middletown. Two birds were analyzed separately, the weights of both together being: undrawn, 1928 grams; drawn, 1592, grams; bones, 259 grams; giblets, 129 grams.

Nos. 3598–3601. Pigeon. Raised in Middletown. Six pigeons were analyzed in pairs, the total weights for all six being: drawn carcass, 1327 grams; giblets, 190 grams; bones, 180 grams.

Nos. 3613–3615. Pheasant. Two live male birds were obtained from the Canadian Pheasantry. The total weights of both when dressed were: undrawn, 2041 grams; drawn, 1828 grams; giblets, 114 grams; bones, 219 grams.

Nos. 3574–3576. Quail. Wild birds shot in the vicinity of Middletown. Two birds in fine condition were brought to the laboratory and dressed. The weights of the two quails were as follows: as received at the laboratory, 368 grams; with feathers, head and feet removed, 322 grams; drawn, 276 grams; giblets, 32 grams; bones, 29 grams. There was little difference in the two birds as regards these various weights. The giblets were so small in amount that the total for the two birds was ground and analyzed together.

Nos. 3616–3618. Russian Pheasant. Two cold storage birds were obtained from New York market. The weights were: undrawn, 2098 grams; drawn, 1589 grams; giblets, 195 grams; bones, 222 grams.

Nos. 3547–3550. Squab. Raised in Middletown. The birds were plump and fine. Six squabs were obtained, and these were analyzed in pairs. The total weight of one pair, including hearts and gizzards, was 353 grams; the hearts and gizzards weighed 34 grams, and the bones 55.3 grams. The total weight of the second pair was 368 grams, giblets 32 grams and bones 60.4 grams; and the weights for the third pair were, total 350 grams, giblets 29 grams, bones 51.3 grams.

Nos. 3589–3594. Turkey. Raised in the vicinity of Middletown. Two turkeys were analyzed, their weights together being: undrawn, 6804 grams; drawn, 6448 grams; giblets, 600 grams; bones, 926 grams.

Nos. 3581, 3582. Turkey meat cooked by roasting. Light and dark meat, respectively, but from different birds.

No. 3619. Potted turkey. A standard brand packed in Kansas. The contents of three cans were mixed for analysis. No. 3628. Potted turkey packed in Delaware. The contents of one can were analyzed.

No. 3620. Potted chicken. A standard brand packed in Illinois. The contents of three cans were mixed for analysis. No. 3627. Potted chicken packed in Delaware. The contents of one can analyzed.

Nos. 3621–3623. Chicken soup. Standard varieties, the two former prepared in Indiana, and the latter in Delaware. The contents of the three cans were analyzed separately.

No. 3624. Chicken gumbo (Okra). Prepared in New Jersey. The contents of one can used for analysis.

No. 3625. Boned chicken. Prepared in Delaware. Contents of one can analyzed.

No. 3626. Terrine de Foie Gras. Prepared in France. The contents of one jar were analyzed.

Nos. 3629, 3630. Smoked goose breast. Obtained in New York market. The former sample was analyzed whole, including the skin and fat; in the case of the latter the skin and fat were removed from the outside, and only the lean flesh was analyzed.

ANALYSIS OF SAMPLES.

The methods of analysis were those recommended by the Association of Official Agricultural Chemists,* with such modifications as have been found advantageous in this laboratory. The determinations of the heats of combustion were made by means of the bomb calorimeter.† The analytical data for the fresh samples are given in Table 23 below. The poultry as purchased given in the table indicates the total carcass dressed and drawn, but including the giblets. The edible portion is the same thing but with the bones removed; *i. e.*, it is the total amount of edible material in the bird. The "meat" is the flesh of the bird, not including the giblets. The giblets include the heart, liver, lungs and gizzard, that are usually utilized in making gravy, soup, etc. The composition of the water-free edible material is given in Table 24.

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* U. S. Dept. Agr., Bureau of Chemistry, Bul. 46 revised.

† Storrs Station Report, 1897, p. 199; and Jour. Am. Chem. Soc., 1903, p. 659.

TABLE 23.

Composition of poultry including refuse and water.

Lab. No.	Food Material.	Refuse.	Water.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	%	%	Cal.
	Capon, as purchased,	17.9	45.6	17.1	18.7	—	0.8	2.680
	Capon, as purchased,	17.0	47.9	18.3	16.3	—	1.1	2.475
	Average,	**17.5**	**46.8**	**17.7**	**17.5**	—	**1.0**	**2.580**
	Capon, edible portion,	—	55.6	20.8	22.8	—	1.0	3.260
	Capon, edible portion,	—	57.7	22.1	19.6	—	1.3	2.980
	Average,	—	**56.7**	**21.5**	**21.2**	—	**1.2**	**3.120**
3609	Capon, meat,	—	54.4	20.9	24.0	—	1.0	3.368
3611	Capon, meat,	—	57.2	22.2	20.1	—	1.3	3.075
	Average,	—	**55.8**	**21.6**	**22.1**	—	**1.2**	**3.222**
3610	Capon, giblets,	—	64.7	19.8	13.7	—	1.3	2.484
3612	Capon, giblets,	—	61.9	21.1	15.5	—	1.3	2.608
	Average,	—	**63.3**	**20.5**	**14.6**	—	**1.3**	**2.546**
	Chicken, as purchased,	19.1	52.3	17.6	10.4	—	0.8	1.980
	Chicken, as purchased,	19.8	56.1	18.4	5.0	—	0.9	1.500
	Chicken, as purchased,	17.4	58.2	17.3	6.2	—	0.9	1.525
	Average,	**18.8**	**55.5**	**17.8**	**7.2**	—	**0.9**	**1.670**
	Chicken, edible portion,	—	64.7	21.8	12.9	—	1.0	2.450
	Chicken, edible portion,	—	70.0	22.9	6.2	—	1.1	1.870
	Chicken, edible portion,	—	70.4	21.0	7.5	—	1.1	1.845
	Average,	—	**68.4**	**21.9**	**8.9**	—	**1.1**	**2.055**
3559	Chicken, meat,	—	64.2	22.0	13.3	—	1.0	2.504
3560	Chicken, meat,	—	69.5	23.1	6.9	—	1.1	1.914
	Average,	—	**66.9**	**22.6**	**10.1**	—	**1.1**	**2.209**
3595	Chicken, dark meat,	—	70.1	20.8	8.2	—	1.2	1.872
3596	Chicken, light meat,	—	70.3	21.9	7.4	—	1.1	1.845
3557	Chicken, giblets,	—	68.9	19.9	9.1	—	1.3	1.990
3558	Chicken, giblets,	—	73.0	21.4	3.5	—	1.4	1.585
3597	Chicken, giblets,	—	71.0	18.2	6.6	—	1.2	1.783
	Average,	—	**71.0**	**19.8**	**6.4**	—	**1.3**	**1.786**
	Chicken, broilers, as purchased,	24.5	51.6	15.0	7.9	—	0.9	1.555
	Chicken, broilers, as purchased,	26.5	52.3	15.7	4.6	—	0.7	1.275
	Average,	**25.5**	**52.0**	**15.4**	**6.3**	—	**0.8**	**1.415**
	Chicken, broiler, edible portion,	—	68.3	19.9	10.4	—	1.2	2.060
	Chicken, broiler, edible portion,	—	71.1	21.4	6.3	—	1.0	1.735
	Average,	—	**69.7**	**20.7**	**8.3**	—	**1.1**	**1.900**
3668	Chicken, broiler, meat,	—	67.6	20.1	11.1	—	1.2	2.122
3669	Chicken, broiler, meat,	—	70.8	22.0	6.4	—	1.0	1.754
	Average,	—	**69.2**	**21.1**	**8.8**	—	**1.1**	**1.938**
3670	Chicken, broiler, giblets,	—	72.8	18.7	6.1	—	1.3	1.608
	Duck, as purchased,	16.7	53.8	15.6	12.5	—	1.0	2.035
	Duck, as purchased,	15.9	52.3	14.3	15.6	—	1.1	2.270
	Duck, as purchased,	15.8	50.9	17.0	14.5	—	1.3	2.310
	Duck, as purchased,	15.0	48.5	14.8	21.4	—	0.9	2.870
	Average,	**15.9**	**51.4**	**15.4**	**16.0**	—	**1.1**	**2.370**
	Duck, edible portion,	—	64.6	18.7	15.0	—	1.2	2.445
	Duck, edible portion,	—	62.2	17.0	18.6	—	1.6	2.700
	Duck, edible portion,	—	60.5	20.2	17.2	—	1.3	2.745
	Duck, edible portion,	—	57.0	17.4	25.2	—	1.0	3.295
	Average,	—	**61.1**	**18.3**	**19.0**	—	**1.3**	**2.795**

TABLE 23.—(*Continued.*)

Lab. No.	Food Material.	Refuse.	Water.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	%	%	Cal.
3565	Duck, meat (not including breast),	—	60.0	18.4	20.2	—	1.1	2.913
3568	Duck, meat (not including breast),	—	57.3	15.5	25.7	—	0.9	3.259
3571	Duck, meat (not including breast),	—	55.3	19.6	23.5	—	1.1	3.299
3602	Duck, meat (not including breast),	—	49.4	16.0	34.8	—	0.8	4.110
	Average,	—	**55.5**	**17.4**	**26.1**	—	**1.0**	**3.395**
3566	Duck, breast,	—	75.9	20.4	1.7	—	1.3	1.363
3569	Duck, breast,	—	73.0	23.6	2.1	—	1.4	1.560
3572	Duck, breast,	—	75.0	21.6	2.1	—	1.3	1.433
3603	Duck, breast,	—	71.6	23.6	3.3	—	1.3	1.687
	Average,	—	**73.9**	**22.3**	**2.3**	—	**1.3**	**1.511**
3567	Duck, giblets,	—	75.3	18.1	3.5	—	1.8	1.390
3570	Duck, giblets,	—	73.4	17.7	3.8	—	1.6	1.518
3573	Duck, giblets,	—	70.2	20.9	3.7	—	2.1	1.708
3604	Duck, giblets,	—	73.9	15.0	8.9	—	1.5	1.714
	Average,	—	**73.2**	**17.9**	**5.0**	—	**1.8**	**1.583**
	Duckling, as purchased,	14.5	43.7	11.6	29.5	—	0.7	3.430
	Duckling, as purchased,	17.8	42.9	12.3	26.5	—	0.7	3.140
	Average,	**16.2**	**43.3**	**12.0**	**28.0**	—	**0.7**	**3.285**
	Duckling, edible portion,	—	51.1	13.6	34.5	—	0.8	4.010
	Duckling, edible portion,	—	52.2	14.9	32.2	—	0.9	3.820
	Average,	—	**51.7**	**14.3**	**33.4**	—	**0.9**	**3.915**
3605	Duckling, meat,	—	48.1	12.9	38.5	—	0.7	4.343
3607	Duckling, meat,	—	48.5	14.0	37.3	—	0.7	4.262
	Average,	—	**48.3**	**13.5**	**37.9**	—	**0.7**	**4.305**
3606	Duckling, giblets,	—	69.7	18.3	9.7	—	1.5	1.979
3608	Duckling, giblets,	—	70.7	19.5	6.5	—	1.7	1.705
	Average,	—	**70.2**	**18.9**	**8.1**	—	**1.6**	**1.842**
	Fowl, as purchased,	15.6	46.1	15.7	21.9	—	0.8	2.882
	Fowl, as purchased,	16.6	53.7	18.4	10.4	—	1.0	1.999
	Average,	**16.1**	**49.9**	**17.1**	**16.2**	—	**0.9**	**2.441**
	Fowl, edible portion,	—	54.6	18.6	25.9	—	1.0	3.415
	Fowl, edible portion,	—	64.4	22.1	12.5	—	1.2	2.397
	Average,	—	**59.5**	**20.4**	**19.2**	—	**1.1**	**2.906**
3563	Fowl, meat,	—	54.1	18.6	26.5	—	1.0	3.461
3564	Fowl, meat,	—	63.7	22.4	13.2	—	1.2	2.460
	Average,	—	**58.9**	**20.5**	**19.9**	—	**1.1**	**2.961**
3561	Fowl, giblets,	—	59.3	18.1	20.0	—	1.2	2.965
3562	Fowl, giblets,	—	70.1	19.3	7.3	—	1.3	1.922
	Average,	—	**64.7**	**18.7**	**13.7**	—	**1.3**	**2.444**
	Goose, as purchased,	11.3	48.9	14.3	24.8	—	0.8	3.133
	Goose, as purchased,	10.9	47.1	15.2	26.1	—	1.1	3.328
	Average,	**11.1**	**48.0**	**14.8**	**25.5**	—	**1.0**	**3.231**
	Goose, edible portion,	—	55.1	16.1	28.0	—	0.9	3.532
	Goose, edible portion,	—	52.8	17.1	29.3	—	1.2	3.735
	Average,	—	**54.0**	**16.6**	**28.7**	—	**1.1**	**3.634**
3555	Goose, meat,	—	53.1	15.6	30.7	—	0.8	3.745
3556	Goose, meat,	—	50.4	16.7	32.3	—	1.1	3.990
	Average,	—	**51.8**	**16.2**	**31.5**	—	**1.0**	**3.868**
3552	Goose, giblets,	—	70.0	20.1	8.2	—	1.7	2.002

TABLE 23.—*(Continued.)*

Lab. No.	Food Material.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of com. per gram.
		%	%	%	%	%	%	Cal.
	Green goose, as purchased,	9.2	43.5	13.4	33.1	—	0.8	3.895
	Green goose, as purchased,	9.9	43.6	14.0	32.0	—	0.8	3.814
	Average,	**9.6**	**43.6**	**13.7**	**32.6**	—	**0.8**	**3.855**
	Green goose, edible portion,		47.9	14.7	36.5	—	0.9	4.290
	Green goose, edible portion,		48.4	15.5	35.5	—	0.9	4.233
	Average,		**48.2**	**15.1**	**36.0**	—	**0.9**	**4.262**
3553	Green goose, meat,		45.3	13.8	40.1	—	0.8	4.557
3554	Green goose, meat,		46.1	14.8	38.7	—	0.8	4.470
	Average,		**45.7**	**14.3**	**39.4**	—	**0.8**	**4.514**
3551	Green goose, giblets,		68.7	22.3	7.3	—	1.4	2.192
	Guinea hen, as purchased,	15.4	57.7	19.5	6.1	—	1.1	1.689
	Guinea hen, as purchased,	17.4	57.7	19.2	4.7	—	1.0	1.502
	Average,	**16.4**	**57.7**	**19.4**	**5.4**	—	**1.1**	**1.596**
	Guinea hen, edible portion,		68.2	23.0	7.2	—	1.3	1.997
	Guinea hen, edible portion,		69.9	23.2	5.7	—	1.2	1.819
	Average,		**69.1**	**23.1**	**6.5**	—	**1.3**	**1.908**
3577	Guinea hen, meat,		68.4	23.2	7.0	—	1.3	1.976
3579	Guinea hen, meat,		69.4	23.6	5.9	—	1.2	1.850
	Average,		**68.9**	**23.4**	**6.5**	—	**1.3**	**1.913**
3578	Guinea hen, giblets,		66.4	21.3	9.6	—	1.4	2.183
3580	Guinea hen, giblets,		73.3	20.2	4.5	—	1.1	1.592
	Average,		**69.9**	**20.8**	**7.1**	—	**1.3**	**1.888**
	Pheasant, as purchased,	12.5	61.7	21.6	3.3	—	1.1	1.522
	Pheasant, as purchased,	11.5	61.3	21.3	5.1	—	0.8	1.654
	Average,	**12.0**	**61.5**	**21.5**	**4.2**	—	**1.0**	**1.588**
	Pheasant, edible portion,		70.5	24.7	3.8	—	1.3	1.739
	Pheasant, edible portion,		69.3	24.0	5.8	—	0.9	1.869
	Average,		**69.9**	**24.4**	**4.8**	—	**1.1**	**1.804**
3613	Pheasant, meat,		70.6	25.0	3.5	—	1.3	1.723
3614	Pheasant, meat,		69.3	24.3	5.7	—	0.9	1.863
	Average,		**70.0**	**24.7**	**4.6**	—	**1.1**	**1.793**
3615	Pheasant, giblets,		68.9	20.1	7.2	—	1.6	1.945
	Pigeon, as purchased,	12.9	51.1	20.4	13.7	—	1.3	2.447
	Pigeon, as purchased,	12.9	57.5	20.0	7.7	—	1.2	1.858
	Pigeon, as purchased,	15.1	57.1	18.7	7.1	—	1.3	1.745
	Average,	**13.6**	**55.2**	**19.7**	**9.5**	—	**1.3**	**2.017**
	Pigeon, edible portion,		58.7	23.4	15.8	—	1.5	2.809
	Pigeon, edible portion,		66.0	23.0	8.8	—	1.4	2.133
	Pigeon, edible portion,		67.3	22.0	8.4	—	1.5	2.055
	Average,		**64.0**	**22.8**	**11.0**	—	**1.5**	**2.332**
3598	Pigeon, meat,		56.9	23.7	17.7	—	1.4	2.993
3599	Pigeon, meat,		65.6	23.1	9.5	—	1.3	2.189
3600	Pigeon, meat,		67.2	22.0	9.1	—	1.4	2.096
	Average,		**63.2**	**22.9**	**12.1**	—	**1.4**	**2.426**
3601	Pigeon, giblets,		68.1	22.2	5.2	—	2.3	1.867
	Quail, as purchased,	9.9	60.3	22.5	5.1	—	1.4	1.794
	Quail, as purchased,	11.1	57.7	22.1	7.0	—	1.4	1.937
	Average,	**10.5**	**59.0**	**22.3**	**6.1**	—	**1.4**	**1.866**
	Quail, edible portion,		66.9	25.0	5.7	—	1.6	1.991
	Quail, edible portion,		64.9	24.9	7.9	—	1.6	2.179
	Average,		**65.9**	**25.0**	**6.8**	—	**1.6**	**2.085**

TABLE 23.—*(Continued.)*

Lab. No.	FOOD MATERIAL.	Refuse.	Water.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	%	%	Cal.
3574	Quail, meat,	—	67.5	25.4	5.7	—	1.4	1.969
3575	Quail, meat,	—	65.1	25.4	8.2	—	1.4	2.193
	Average,	—	**66.3**	**25.4**	**7.0**	—	**1.4**	**2.081**
3576	Quail giblets,	—	63.0	21.8	6.2	—	2.3	2.140
	Russian pheasant, as purchased,	13.0	61.2	21.9	2.5	—	1.1	1.366
	Russian pheasant, as purchased,	15.2	61.0	21.0	1.3	—	1.2	1.356
	Average,	**14.1**	**61.1**	**21.5**	**1.9**	—	**1.2**	**1.361**
	Russian pheasant, edible portion,	—	70.3	25.2	3.0	—	1.3	1.570
	Russian pheasant, edible portion,	—	71.9	24.8	1.6	—	1.4	1.599
	Average,	—	**71.1**	**25.0**	**2.3**	—	**1.4**	**1.585**
3616	Russian pheasant, meat,	—	69.6	25.9	3.1	—	1.3	1.589
3617	Russian pheasant, meat,	—	71.5	25.4	1.5	—	1.4	1.623
	Average,	—	**70.6**	**25.7**	**2.3**	—	**1.4**	**1.606**
3618	Russian pheasant, giblets,	—	74.4	21.2	2.2	—	1.3	1.467
	Squab, as purchased,	15.6	48.4	15.4	19.4	—	1.2	2.675
	Squab, as purchased,	16.3	47.6	16.0	19.3	—	1.2	2.652
	Squab, as purchased,	14.9	50.9	15.7	17.2	—	1.4	2 493
	Average,	**15.6**	**49.0**	**15.7**	**18.6**	—	**1.3**	**2.607**
	Squab, edible portion,	—	57.3	18.3	23.0	—	1.4	3.170
	Squab, edible portion,	—	56.9	19.0	23.0	—	1.4	3.169
	Squab, edible portion,	—	59.8	18.5	20.2	—	1.6	2.930
	Average,	—	**58.0**	**18.6**	**22.1**	—	**1.5**	**3.090**
3548	Squab, meat,	—	55.7	18.1	25.0	—	1.3	3.351
3549	Squab, meat,	—	55.4	18.9	24.8	—	1.3	3.324
3550	Squab, meat,	—	58.7	18.4	21.6	—	1.6	3.049
	Average,	—	**56.6**	**18.5**	**23.8**	—	**1.4**	**3.241**
3547	Squab, giblets,	—	69.8	19.8	7.2	—	2.0	1.837
	Turkey, as purchased,	15.3	47.9	18.0	17.1	—	0.9	2.660
	Turkey, as purchased,	13.3	50.5	20.0	15.3	—	1.0	2.502
	Average,	**14.3**	**49.2**	**19.0**	**16.2**	—	**1.0**	**2.581**
	Turkey, edible portion,	—	56.6	21.3	20.2	—	1.1	3.141
	Turkey, edible portion,	—	58.2	23.1	17.6	—	1.2	2.886
	Average,	—	**57.4**	**22.2**	**18.9**	—	**1.2**	**3.014**
3589	Turkey, dark meat,	—	52.1	19.0	26.1	—	1.0	3.606
3592	Turkey, dark meat,	—	54.3	21.0	23.8	—	1.1	3.303
	Average,	—	**53.2**	**20.0**	**25.0**	—	**1.1**	**3.455**
3590	Turkey, light meat,	—	61.7	25.1	12.2	—	1.3	2.569
3593	Turkey, light meat,	—	62.4	26.5	10.4	—	1.2	2.374
	Average,	—	**62.1**	**25.8**	**11.3**	—	**1.3**	**2.472**
	Turkey, light and dark meat, average,	—	**57.7**	**22.9**	**18.2**	—	**1.2**	**2.963**
3591	Turkey, giblets,	—	56.2	17.1	25.1	—	1.2	3.300
3594	Turkey, giblets,	—	57.2	18.2	21.8	—	1.2	3.231
	Average,	—	**56.7**	**17.7**	**23.5**	—	**1.2**	**3.266**
3581	Turkey, dark meat, cooked,	—	53.7	39.2	4.3	—	2.2	2.648
3582	Turkey, light meat, cooked,	—	58.5	34.6	4.9	—	1.8	2.401
3619	Potted turkey,	—	64.9	12.3	15.8	—	3.2	2.323
3628	Potted turkey,	—	47.0	22.1	28.1	—	2.7	3.905
	Average,	—	**56.0**	**17.2**	**22.0**	—	**3.0**	**3.114**
3620	Potted chicken,	—	64.4	15.8	14.0	—	2.4	2.368
3627	Potted chicken,	—	47.7	22.9	26.5	—	2.6	3.762
	Average,	—	**56.1**	**19.4**	**20.3**	—	**2.5**	**3.065**

TABLE 23.—(*Continued.*)

Lab. No.	FOOD MATERIAL.	Refuse.	Water.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	%	%	Cal.
3621	Canned chicken soup, - - -	—	85.0	2.6	4.1	6.5	1.8	0.790
3622	Canned chicken soup, - - -	—	81.4	3.0	5.8	7.7	2.1	1.005
3623	Canned chicken soup, - - -	—	95.0	3.0	—	1.1	0.9	0.194
	Average, - - - - - -	—	**87.1**	**2.9**	**3.3**	**5.1**	**1.6**	**0.663**
3624	Canned chicken gumbo soup, - -	—	91.0	2.4	0.2	4.8	1.6	0.351
3625	Canned boned chicken, - - -	—	57.6	27.7	12.8	—	2.2	2.745
3629	Smoked goose breast (including skin and fat), - - - - - -	—	35.7	20.1	38.7	—	5.5	4.874
3630	Smoked goose breast (skin and fat removed from outside, - -	—	61.3	26.1	4.4	—	8.0	1.867
3626	Terrine de Foie Gras, - - -	—	41.3	13.6	38.2	4.3	2.6	4.578

TABLE 24.

Composition of poultry, water-free substance.

Lab. No.	Food Material.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	Cal.
3609	Capon, meat,	45.76	52.63	—	2.26	7.391
3611	Capon, meat,	51.95	46.92	—	3.02	7.185
	Average,	**48.86**	**49.78**	—	**2.64**	**7.288**
3610	Capon, giblets,	56.14	38.76	—	3.80	7.040
3612	Capon, giblets,	55.39	40.74	—	3.49	6.853
	Average,	**55.77**	**39.75**	—	**3.65**	**6.947**
3559	Chicken, meat,	61.35	37.21	—	2.79	6.988
3560	Chicken, meat,	75.57	22.60	—	3.51	6.269
	Average,	**68.46**	**29.91**	—	**3.15**	**6.629**
3595	Chicken, dark meat,	69.50	27.50	—	3.94	6.249
3596	Chicken, light meat,	73.49	24.92	—	3.61	6.204
3557	Chicken, giblets,	63.81	29.36	—	4.16	6.399
3558	Chicken, giblets,	79.33	12.99	—	5.08	5.864
3597	Chicken, giblets,	62.84	22.73	—	3.98	6.156
	Average,	**68.66**	**21.69**	—	**4.41**	**6.140**
3668	Chicken, broiler, meat,	62.13	34.24	—	3.51	6.552
3669	Chicken, broiler, meat,	75.61	21.83	—	3.37	6.011
	Average,	**68.87**	**28.04**	—	**3.44**	**6.282**
3670	Chicken, broiler, giblets,	68.67	22.45	—	4.83	5.919
3565	Duck meat (not including breast),	45.94	50.56	—	2.67	7.288
3568	Duck meat (not including breast),	36.28	60.06	—	2.13	7.633
3571	Duck meat (not including breast),	43.93	52.54	—	2.38	7.383
3602	Duck meat (not including breast),	31.68	68.76	—	1.67	8.129
	Average,	**39.46**	**57.98**	—	**2.21**	**7.608**
3566	Duck, breast,	84.45	7.03	—	5.27	5.654
3569	Duck, breast,	87.56	7.81	—	5.22	5.783
3572	Duck, breast,	86.41	8.40	—	5.21	5.731
3603	Duck, breast,	83.22	11.51	—	4.63	5.940
	Average,	**85.41**	**8.69**	—	**5.08**	**5.777**
3567	Duck, giblets,	73.52	13.98	—	7.11	5.634
3570	Duck, giblets,	66.44	14.21	—	6.15	5.698
3573	Duck, giblets,	70.00	12.25	—	6.98	4.308
3604	Duck, giblets,	57.31	33.99	—	5.82	6.556
	Average,	**66.82**	**18.61**	—	**6.52**	**5.549**
3605	Duckling, meat,	24.89	74.19	—	1.37	8.378
3607	Duckling, meat,	27.18	72.32	—	1.33	8.267
	Average,	**26.04**	**73.26**	—	**1.35**	**8.323**
3606	Duckling, giblets,	60.49	31.83	—	4.86	6.529
3608	Duckling, giblets,	66.31	22.19	—	5.64	5.813
	Average,	**63.40**	**27.01**	—	**5.25**	**6.171**
3563	Fowl, meat,	40.63	57.68	—	2.12	7.546
3564	Fowl, meat,	61.79	36.48	—	3.28	6.776
	Average,	**51.21**	**47.08**	—	**2.70**	**7.161**
3561	Fowl, giblets,	44.51	49.13	—	2.95	7.336
3562	Fowl, giblets,	64.52	24.48	—	4.29	6.416
	Average,	**54.52**	**36.81**	—	**3.62**	**6.876**
3555	Goose, meat,	33.30	65.40	—	1.77	7.980
3556	Goose, meat,	33.76	65.02	—	2.22	8.042
	Average,	**33.53**	**65.21**	—	**2.00**	**8.011**
3552	Goose, giblets,	67.02	27.33	—	5.56	6.670

TABLE 24.—*(Continued.)*

Lab. No.	Food Material.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	Cal.
3553	Green goose, meat,	25.29	73.30	—	1.52	8.338
3554	Green goose, meat,	27.49	71.80	—	1.56	8.295
	Average,	**26.39**	**72.55**	—	**1.54**	**8.317**
3551	Green goose, giblets,	71.38	23.29	—	4.49	7.010
3577	Guinea hen, meat,	73.28	22.15	—	4.06	6.251
3579	Guinea hen, meat,	77.16	19.31	—	3.99	6.052
	Average,	**75.22**	**20.73**	—	**4.03**	**6.152**
3578	Guinea hen, giblets,	63.34	28.54	—	4.01	6.500
3580	Guinea hen, giblets,	75.70	16.91	—	4.25	5.963
	Average,	**69.52**	**22.73**	—	**4.13**	**6.232**
3613	Pheasant, meat,	84.90	12.01	—	4.46	5.850
3614	Pheasant, meat,	78.94	18.65	—	3.07	6.062
	Average,	**81.92**	**15.33**	—	**3.77**	**5.956**
3615	Pheasant, giblets,	64.72	23.24	—	5.17	6.250
3598	Pigeon, meat,	54.96	41.00	—	3.32	6.944
3599	Pigeon, meat,	67.00	27.57	—	3.89	6.364
3600	Pigeon, meat,	67.12	27.71	—	4.26	6.398
	Average,	**63.03**	**32.09**	—	**3.82**	**6.569**
3601	Pigeon, giblets,	69.52	16.34	—	7.27	5.860
3574	Quail, meat,	78.36	17.65	—	4.43	6.068
3575	Quail, meat,	72.66	23.44	—	4.05	6.285
	Average,	**75.51**	**20.55**	—	**4.24**	**6.177**
3576	Quail, giblets,	58.84	16.78	—	6.18	5.780
3616	Russian pheasant, meat,	85.04	10.24	—	4.30	5.914
3617	Russian pheasant, meat,	89.22	5.37	—	5.03	5.696
	Average,	**87.13**	**7.81**	—	**4.67**	**5.805**
3618	Russian pheasant, giblets,	82.57	8.41	—	5.13	5.730
3548	Squab, meat,	40.89	56.38	—	2.83	7.558
3549	Squab, meat,	42.28	55.50	—	2.82	7.451
3550	Squab, meat,	44.55	52.20	—	3.83	7.375
	Average,	**42.57**	**54.69**	—	**3.16**	**7.461**
3547	Squab, giblets,	65.74	23.85	—	6.53	6.092
3589	Turkey, dark meat,	39.68	54.44	—	2.17	7.635
3592	Turkey, dark meat,	45.90	52.10	—	2.37	7.220
	Average,	**42.79**	**53.27**	—	**2.27**	**7.428**
3590	Turkey, light meat,	65.54	31.90	—	3.27	6.656
3593	Turkey, light meat,	70.40	27.59	—	3.16	6.317
	Average,	**67.97**	**29.75**	—	**3.22**	**6.487**
3591	Turkey, giblets,	39.08	57.30	—	2.62	7.514
3594	Turkey, giblets,	42.51	50.98	—	2.71	7.548
	Average,	**40.80**	**54.14**	—	**2.67**	**7.531**
3581	Turkey, dark meat, cooked,	84.64	9.21	—	4.78	5.713
3582	Turkey, light meat, cooked,	83.26	11.90	—	4.26	5.780
3619	Potted turkey,	35.03	44.97	—	9.07	6.623
3628	Potted turkey,	41.61	53.07	—	5.10	7.369
	Average,	**38.32**	**49.02**	—	**7.09**	**6.996**
3620	Potted chicken,	44.45	39.36	—	6.72	6.653
3627	Potted chicken,	43.77	50.74	—	5.06	7.204
	Average,	**44.11**	**45.05**	—	**5.89**	**6.929**
3621	Canned chicken soup,	17.46	27.09	43.33	12.12	5.248
3622	Canned chicken soup,	16.04	31.28	41.28	11.40	5.390
3623	Canned chicken soup,	59.35	.62	21.94	18.09	3.860
	Average,	**30.95**	**19.66**	**35.52**	**13.87**	**4.833**

TABLE 24.—*(Continued.)*

Lab. No.	FOOD MATERIAL.	Protein.	Fat.	Carbohydrates	Ash.	Heat of com. per gram.
		%	%	%	%	Cal.
3624	Canned chicken gumbo soup,	26.35	2.19	53.47	17.99	3.880
3625	Canned boned chicken,	65.38	30.20	—	5.28	6.474
3629	Smoked goose breast (including skin and fat),	31.32	60.12	—	8.58	7.577
3630	Smoked goose breast (skin and fat removed from outside),	67.53	11.48	—	20.66	4.830
3626	Terrine de Foie Gras,	23.12	65.01	7.41	4.46	7.797

POULTRY AS FOOD.

BY R. D. MILNER.

To many people the word "poultry" refers simply to hens and chickens, the kinds which appear oftenest in the city markets; but the proper definition of the term is "birds domesticated for their eggs or flesh." It is obvious from this definition that the kinds of birds to be designated as poultry may differ in different parts of the world. In olden days pea-fowl, which with us are bred mainly if not wholly for ornament, were raised as poultry; pigeon may sometimes be poultry, as when bred for the table, and sometimes not, as when they are bred for carriers or ornament.

The ordinary American sorts of poultry are common fowl, turkeys, guinea-fowl, ducks, geese and squabs; to these pheasant and quail should perhaps be added, as they are being bred more and more in this country, as yet mainly for sport, but increasingly also for the markets. Of these varieties common fowl, turkeys, ducks and geese are by far the most important. They will thrive in all but the severest climates, and can often be raised on lands too poor to produce profitable crops. Common fowl are, of course, bred to a much greater extent than any of the other kinds of poultry. In the majority of cases they are bred primarily for their eggs, over a billion and a quarter dozens of eggs, valued at more than one hunded and forty-four million dollars, being produced in the United States in 1899. A large proportion of the hens ultimately find their way to the table, however, and many chickens are raised primarily for their flesh. According to the census of 1900,* 88.8 per cent. of the 5,739,657 farms in the United States were reported as raising poultry, whose total value in 1899 was estimated at $136,891,877. The following table shows how the poultry is distributed among the different parts of the country.

* 12th Census of the U. S., Vol. V. Part I., pp. ccxxvii.-ccxxvx. and 630-672.

TABLE 25.

Distribution of poultry in the United States.

Section.	Per cent. of farms reporting poultry.	Chickens, including Guinea fowl.	Turkeys.	Geese.	Ducks.
United States, - - -	88.8	233,598,035	6,599,367	5,676,863	4,807,358
North Atlantic States, -	89.4	27,952,114	529,932	144,527	453,580
South Atlantic States, -	88.3	22,293,912	810,975	908,908	458,918
North Central States, -	91.7	123,469,068	3,072,456	1,899,026	2,416,327
South Central States, -	86.9	50,299,631	1,876,382	2,589,164	1,257,048
Western States, - -	75.8	9,551,296	304,950	135,163	199,977
Alaska and Hawaii, - -	42.5	32,064	4,672	75	21,508

From this it appears that in the North Central States there is the largest number of farms on which poultry is raised and also that more birds of each kind, except geese, are produced in this section than in any other; that it is, in fact, the leading poultry section. The North Atlantic States come next in percentage of farms raising poultry, but the South Central States produce greater numbers of birds of all four kinds, and the South Atlantic States greater numbers of all kinds save chickens. This would seem to indicate that while more of the North Atlantic farmers kept poultry, the Southern farmers kept larger flocks, especially of geese, turkeys and ducks. The birds require a little more care in the colder regions, and feed and labor may be a little more expensive, but perhaps no more so in New England than in Iowa, which is the banner state in the poultry industry. Nor are other agricultural industries so much more productive in the Northeast as to drive out the poultry business. Under present conditions it may perhaps be impossible for the Eastern States to compete with the Western in the production of the staple grains; the climate of New England may prevent the section as a whole from equalling the Southern States, or possibly even New York and New Jersey, in growing fruit and many garden vegetables; but poultry-raising is one of the branches of agriculture exceptionally well adapted to its climate and the character of its land. The reason why it has not been more extensively developed in this section is doubtless that the farmers have not realized the profit which can be made from large flocks of well cared for poultry.

Poultry, especially ducks and geese, has heretofore played a much larger part in the diet of Europeans than in that of people in the United States, but the demand for all kinds of poultry is constantly increasing in this country and the man who can produce well-bred, well-dressed birds for our city markets has a good chance of profit. Within the last few years large poultry farms have sprung up all about New York City, notably on Long Island, and are said to be very prosperous. Under the stimulus of the Experiment Station at Kingston, R. I., not only the number but also the quality of the birds raised in that state has been decidedly improved, to the great advantage of the farmers. If Rhode Island, with about one-fifth as many farms as Connecticut, can produce about one-half as many chickens, two-thirds as many turkeys and ducks and twice as many geese with profit to the breeders, why should not Connecticut farmers be able to develop this branch of agriculture advantageously? Table 26 shows how the poultry of various kinds is distributed through the counties of Connecticut.

TABLE 26.

Distribution of poultry by counties in Connecticut.

County.	Chickens including guinea fowl.	Turkeys.	Geese.	Ducks.
Fairfield,	196,842	1,860	580	4,126
Hartford,	179,857	321	293	1,869
Litchfield,	143,439	1,320	159	1,415
Middlesex,	68,611	275	214	616
New Haven,	161,647	380	731	3,186
New London,	143,609	3,186	1,078	1,846
Tolland,	78,518	198	164	474
Windham,	100,503	177	311	568
Total State,	1,073,026	7,717	3,530	14,100

Fairfield County appears to produce the largest number of birds, and next to it comes Hartford. Third in total numbers is New London County, but the latter leads in the number of turkeys and geese. Middlesex and Tolland Counties give the smallest showing, though it is hard to understand why birds might not be raised in them with as much success as in the neighboring counties of Hartford and New London.

A study of these figures and a comparison with Rhode Island and Long Island, where the natural conditions are not very different, leads one to the conclusion that Connecticut farmers in general have not yet appreciated the advantages which come from systematic and intelligent poultry-raising, especially of turkeys, ducks and geese.

So much information concerning the breeds, management and feed of common fowl is being constantly printed in experiment station publications and agricultural papers of all kinds that it is unnecessary to discuss those subjects here. Nor is this the place for detailed description of the breeding and care of other kinds of poultry. It will not be out of place, however, to speak briefly of the general conditions needed for turkeys, ducks and geese.

In some ways, turkeys are the most difficult of the poultry-kind to raise. They are shy and wild, are often put out of condition by fright, and are subject to various diseases, especially if kept in damp places without sufficient range. Nevertheless in dry, open ranges, and with intelligent care they thrive well and make a very profitable market-bird.

Ducks have not until recently been generally considered desirable table-birds in this country. This was very likely due to the way in which they were raised. Little care was given them, they were allowed to range and swim at will and to eat what they could find and liked; the result was that the flesh was tough and coarse and the flavor very strong and suggestive of the worms and fish on which they fed. When carefully reared and fed with reference to the quality and flavor of the flesh they can be made tender and pleasant to the taste. It is such carefully bred ducks that the market demands and which bring the raiser the greatest profit. It was formerly supposed that ducks would thrive only when they had access to a pond or stream, but it has been found that they will do perfectly well with only enough water for drinking and bathing. Duck raising thus becomes possible on any farm where the climate is not too severe, and as the birds are healthy and easy to raise, it ought to be profitable almost anywhere in Southern New England.

Geese, on the other hand, must have access to running water and green pasturage to thrive best. Like turkeys, too, they must be tactfully handled, for they are very "touchy" birds

and likely to be put out of condition by careless treatment. But with intelligent handling and a good range they will thrive with comparatively little care, finding a large part of their own food and keeping strong and healthy. Their flesh, like that of ducks, is coming more and more into demand, and while it brings a lower price than turkeys, young chickens and even ducks, the cost of production is so much less that the percentage of profits is still good. Goose-raising is therefore to be strongly recommended to Connecticut farmers, especially those who have low, damp lands unsuited for other purposes.

Though these four kinds of poultry are the only ones raised in sufficiently large numbers to furnish statistics for the census, the various "fancy" varieties are becoming more and more common and are said to bring good profits to the raisers. Pheasants are bred in large establishments in various parts of the country, and command good prices as aviary birds or as stock for game-preserves. Many of them end in the meat market, but as yet they are seldom if ever sold by the breeders for table birds. It would seem as if a large farm near a good market might be able to supply the poultry dealers direct, for the birds are in great demand for hotels, restaurants and private families, and bring enormous prices. Pheasants have been successfully raised in New Jersey, Vermont, and on Long Island, and would probably thrive in the warmer, less exposed sections of Connecticut. Squabs, as the young of pigeons are called, are also in constant demand and bring good prices. They are said to be fairly easy to raise and have been successfully grown in this State, so that the chances of breeding them with profit would seem excellent.

Guinea-fowl are classed in the census with common fowl, doubtless because they are hardly ever raised in this country save in small numbers on a farm with other poultry. They are bred in large quantities in Austria and their flesh is much sought after there. There is some demand for it in American markets, and doubtless this demand would increase if the supply were increased, for they make excellent eating and can be had at seasons when game is scarce. A guinea-fowl farm, located where the cries of the birds would not be a disturbance, might make a paying investment. The birds will thrive anywhere that common fowl will.

Of course in order to make poultry raising on a large scale successful the breeder must be near enough to a railroad and a market to be able to ship his birds quickly and cheaply. In this respect Connecticut with its network of railways and its central location between the important markets of Boston and New York, as well as the local markets of its own cities and towns, is exceptionally well adapted to the industry. The breeder must also understand his birds and his market thoroughly. The art of fattening table-fowl, which has always been practiced in Europe, is becoming more and more common in this country and in order to compete with the best producers a breeder must understand, not only how long and how much to feed, but also what effect different kinds of feed and different conditions generally have on the quality, flavor and even color of the flesh. The market also demands good looking, clean-picked birds, and the successful raiser must be careful that the birds are kept clean and free from disease, are properly killed, neatly plucked and carefully packed. He must also study the demands of the dealers at different seasons and know whether he can do better to save his birds for one season's breeding (and in the case of common fowl for eggs), or fatten and market their young as "broilers," ducklings and green geese. Complicated as all these considerations may seem to make the poultry business, they need not frighten any one where the conditions are favorable. The experiment stations of this country and Canada have made a great many investigations and experiments along this line, and there is an abundance of reliable, practical and readable literature on all branches of the subject, to be had often for the asking by anyone who will take the pains to look it up.

While the Storrs Station has not done much special work as regards the breeding, care and management of poultry, it has studied the question of the value of poultry-flesh as food in connection with its other food investigations. This last year analyses have been made of the flesh of various kinds of poultry, the results of which are given in Table 23 in the preceding article. Many of these analyses are the first of their kind to be published and throw much light on the relative values of the different kinds of poultry as food.

TABLE 27.

Proportions of digestible nutrients and fuel value per pound in poultry.

KIND OF FOOD MATERIAL.	Refuse.	Water.	Total indigestible nutrients.	DIGESTIBLE NUTRIENTS. Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per lb.
	%	%	%	%	%	%	%	Cal.
Capon, as purchased, - - - -	17.5	46.8	1.6	17.2	16.6		0.8	1021
Capon, edible portion, - - -		56.7	2.0	20.9	20.1		0.9	1237
Capon, flesh,* - - - - - -		55.8	2.0	21.0	21.0		0.9	1277
Capon, giblets, - - - - - -		63.3	1.6	19.9	13.9		1.0	956
Chicken, as purchased, - - - -	18.8	55.5	1.1	17.3	6.8		0.7	609
Chicken, edible portion, - - -		68.4	1.4	21.2	8.5		0.8	753
Chicken, flesh,* - - - - -		66.9	1.5	21.9	9.6		0.8	813
Chicken, dark meat, - - - - -		70.1	1.3	20.2	7.8		0.9	705
Chicken, light meat, - - - - -		70.3	1.4	21.2	7.0		0.8	690
Chicken, giblets, - - - - -		71.0	1.2	19.2	6.1	1.5	1.0	642
Chicken, broiler, as purchased, - -	25.5	51.9	1.1	14.9	6.0		0.6	531
Chicken, broiler, edible portion, -		69.7	1.4	20.0	8.1		0.8	713
Chicken, broiler, flesh,* - - -		69.2	1.3	20.4	8.3		0.8	729
Chicken, broiler, giblets, - - -		72.8	2.3	18.1	5.8		1.0	582
Duck, as purchased, - - - - -	15.9	51.4	1.6	14.9	15.2		0.8	919
Duck, edible portion, - - - -		61.1	1.8	17.8	18.0		1.0	1090
Duck, flesh,* not including breast, -		55.5	2.0	16.9	24.8		0.8	1362
Duck, breast, - - - - - -		73.9	1.1	21.6	2.2		1.0	494
Duck, giblets, - - - - - -		73.2	1.2	17.3	4.8	2.1	1.4	564
Duckling, as purchased, - - - -	16.2	43.3	1.9	11.6	26.6		0.6	1338
Duckling, edible portion, - - -		51.7	2.4	13.9	31.7		0.7	1597
Duckling, flesh,* - - - - -		48.3	2.4	13.1	36.0		0.6	1763
Duckling, giblets, - - - - -		70.2	1.4	18.3	7.7	1.2	1.2	687
Fowl, as purchased, - - - - -	16.1	49.9	1.4	16.6	15.4		0.7	959
Fowl, edible portion, - - - -		59.5	1.9	19.8	18.2		0.8	1135
Fowl, flesh,* - - - - - -		58.9	1.9	19.9	18.9		0.8	1167
Fowl, giblets, - - - - - -		64.7	1.6	18.1	13.0	1.6	1.0	915
Goose, as purchased, - - - -	11.1	48.0	1.9	14.4	24.2		0.8	1289
Goose, edible portion, - - - -		54.0	2.2	16.1	27.3		0.8	1452
Goose, flesh,* - - - - - -		51.8	2.3	15.7	29.9		0.8	1554
Goose, giblets, - - - - - -		70.0	1.4	19.5	7.8		1.3	692
Green goose, as purchased, - - -	9.6	43.6	2.2	13.3	31.0		0.6	1555
Green goose, edible portion, - -		48.2	2.5	14.6	34.2		0.7	1715
Green goose, flesh,* - - - - -		45.7	2.6	13.9	37.4		0.6	1837
Green goose, giblets, - - - -		68.7	1.4	21.6	6.9	0.6	1.1	704
Guinea hen, as purchased, - - -	16.4	57.7	1.4	18.8	5.1		0.8	565
Guinea hen, edible portion, - - -		69.1	1.3	22.4	6.2		1.0	678
Guinea hen, flesh,* - - - - -		68.9	1.3	22.7	6.2		1.0	683
Guinea hen, giblets, - - - - -		69.9	1.3	20.2	6.7	0.9	1.0	676
Pheasant, as purchased, - - - -	12.0	61.5	1.0	20.9	4.0		0.8	558
Pheasant, edible portion, - - -		69.9	1.2	23.7	4.6		0.8	635
Pheasant, flesh,* - - - - -		70.0	1.2	24.0	4.4		0.8	632
Pheasant, giblets, - - - - -		68.9	1.4	19.5	6.8	2.2	1.2	691
Pigeon, as purchased, - - - -	13.6	55.2	1.4	19.1	9.0		1.0	735
Pigeon, edible portion, - - - -		64.0	1.7	22.1	10.4		1.1	850
Pigeon, flesh,* - - - - - -		63.2	1.6	22.2	11.5		1.1	898

* Not including giblets.

TABLE 27.—*(Continued.)*

Kind of Food Material.	Refuse.	Water.	Total indigestible nutrients.	Digestible Nutrients. Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per lb.
	%	%	%	%	%	%	%	Cal.
Pigeon, giblets,		68.1	1.6	21.5	4.9	2.2	1.7	648
Quail, as purchased,	10.5	59.0	1.3	21.6	5.8		1.1	647
Quail, edible portion,		65.9	1.4	24.3	6.5		1.2	727
Quail, flesh,*		66.3	1.5	24.6	6.6		1.1	735
Quail, giblets,		63.0	1.6	21.2	5.9	6.6	1.7	767
Russian pheasant, as purchased,	14.1	61.1	1.0	20.9	1.8		0.9	465
Russian pheasant, edible portion,		71.1	1.1	24.3	2.2		1.1	544
Russian pheasant, flesh,*		70.6	1.2	24.9	2.2		1.1	555
Russian pheasant, giblets,		74.4	1.0	20.6	2.1	0.9	1.0	488
Squab, as purchased,	15.6	49.0	1.7	15.2	17.7		1.0	1030
Squab, edible portion,		58.0	2.1	18.0	21.0		1.1	1221
Squab, flesh,*		56.6	2.1	17.9	22.6		1.1	1286
Squab, giblets,		69.8	1.5	19.2	6.8	1.2	1.5	666
Turkey, as purchased,	14.3	49.2	1.2	18.8	15.4		0.8	1000
Turkey, edible portion,		57.4	1.9	21.5	18.0		0.9	1159
Turkey, flesh,*		57.7	1.9	22.2	17.3		0.9	1180
Turkey, dark meat,		53.2	2.1	19.4	23.8		0.8	1366
Turkey, light meat,		62.1	1.7	25.0	10.7		1.0	917
Turkey, giblets,		56.7	2.0	17.2	22.3	0.9	0.9	1278
Turkey, dark meat cooked,		53.7	1.9	38.0	4.1		1.7	880
Turkey, light meat cooked,		58.5	1.6	33.6	4.7		1.4	824
Potted chicken,		64.4	1.9	15.3	13.3	3.3	1.8	931
Potted chicken,		47.7	2.9	22.2	25.2	—	2.0	1518
Chicken soup,		85.0	0.8	2.5	3.9	6.4	1.4	329
Chicken soup,		81.3	1.1	2.9	5.5	7.6	1.6	427
Chicken soup,		95.0	0.3	2.9	—	1.1	0.7	77
Chicken gumbo,		91.0	0.6	2.3	0.2	4.7	1.2	138
Boned chicken,		57.6	1.6	26.9	12.2	—	1.7	1058
Terrine de Foie Gras,		41.3	3.0	13.2	36.3	4.2	2.0	1884
Potted turkey,		64.9	2.1	11.9	15.0	3.7	2.4	942
Potted turkey,		47.0	3.0	21.3	26.7	—	2.0	1563
Smoked goose breast with skin and fat,		35.7	3.8	19.6	36.8	—	4.1	1960
Smoked goose breast, skin and fat removed from outside,		61.3	3.2	25.3	4.2	—	6.0	685
Beef, ribs, as purchased,	20.8	43.8	1.8	13.5	20.0	—	.5	1135
Beef, shoulder and clod, as purchased,	16.4	56.8	1.2	15.9	9.3	—	.7	715
Mutton, leg, as purchased,	18.4	51.2	1.4	14.6	14.0	—	.6	890
Pork, loin chops, as purchased,	19.7	41.8	1.8	13.0	23.0	—	.6	1245
Pork, salt, fat, as purchased,	—	7.9	5.4	1.8	81.9	—	2.9	3555
Cod, fresh, dressed, as purchased,	29.9	58.5	0.5	10.8	.2	—	.6	220
Cod, salt, as purchased,	24.9	40.2	5.1	15.5	.4	—	13.9	325
Eggs,	11.2	65.5	1.1	12.7	8.8	—	.7	635
Milk,	—	87.0	0.5	3.2	3.8	5.0	.5	310
Butter,	—	11.0	4.9	1.0	80.8	—	2.3	3410
Wheat flour, patent process,	—	12.0	3.4	9.7	.9	73.6	.4	1635
Bread, white, wheat,	—	35.3	2.9	7.8	1.2	52.0	.8	1200
Beans, white, dried, as purchased,	—	12.6	7.9	17.5	1.6	57.8	2.6	1520
Potatoes, as purchased,	20.0	62.6	1.2	1.5	.1	14.0	.6	695
Apples, as purchased,	25.0	63.3	1.2	.3	.3	9.7	.2	190

* Not including giblets.

The figures given in Table 23 show the percentages of the different ingredients as found by analysis. In Table 27 above the values have been computed so as to show the proportions of digestible nutrients in poultry; and for the sake of comparison and discussion of relative values, corresponding figures are given for a number of common food materials other than poultry.

In order to get at the real meaning of these figures, a few of the main principles of food and its uses in the human body must be borne in mind. Food is taken into the body to build new tissues, fluids, etc., repair old or injured ones, and to furnish heat to keep the body warm and energy for all muscular work, for blood circulation and for breathing as well as for walking or any other activity.

Not all the material in food as it is bought, or even in food ready to eat, is useful to the body. Most foods as purchased contain more or less refuse, or parts which are quite useless as nourishment. The skin and seeds of vegetables, the shells of eggs and the bones of fish and meat are examples of refuse. Moreover there is more or less water in all food materials, and though water is necessary to the well-being of the body, that contained in ordinary solid foods is not counted as adding to the real nutritive value of the food.

Coming to the actual nutrients of the food we find that the materials which are needed to build up the body are the nitrogenous substances called protein and small quantities of mineral matters. The heat and energy are ordinarily supplied mainly by fats and by carbohydrates, of which latter starches and sugars are the main representatives in our food, although protein may also be thus utilized. The protein is found in casein of milk, white of egg, gluten of wheat, etc., and also in the lean of meat. Fats are of course easily recognizable in meats and butter, and occur more or less in vegetable foods, as the oil of corn or wheat, olive oil, etc. The principal sources of carbohydrates are the starches of cereals, vegetables and fruits, and sugars, whether separated or in honey and vegetable foods. Mineral matters are found in small quantities in all our common foods. Meats are especially important in our diet as sources of the tissue-building protein, but they also have a great value for the heat and energy they yield to the body, especially through the fat. The amount of energy or heat

which a given amount and kind of food will furnish to the body is called its fuel value, and is expressed by calories, one calorie representing the energy necessary to lift 1 ton 1.54 feet or to raise the temperature of 1 pound of water 4° F. The fuel value of fats is more than twice as great as that of protein or carbohydrates, and hence materials rich in fat have a relatively high fuel value.

Of course the body is not nourished by what is actually eaten, but what is actually digested, that is by that part of all the food eaten which the digestive organs are able to change into such form that it can be taken into the circulation and used to build tissues or supply heat and energy. The amount thus made useful we speak of as the digestible portion. It differs somewhat with individuals, with the mode of cooking, etc., but in general it is found that about 97 per cent. of the total protein in meats and 95 per cent. of the total fat is digested by the average healthy person, or, in other words the digestibility of animal protein is 97 per cent., and of fats 95 per cent.

In considering the true nutritive value of any food, then, we must know in the first place how much refuse and water it contains. The more of these we find present, the smaller will be the proportion of nutrients; and the greater the proportion of fats and carbohydrates, the higher will be the fuel value.

In discussing the value of poultry as food it may be interesting to notice how the different kinds of meats, taken as a class, compare in nutritive value with the other classes of foods, such as milk, eggs, vegetables, fruits, cereals, bread, etc. The composition of different meats and other foods is given at the bottom of Table 27. It is rather hard to make very general comparisons as the different vegetable foods vary so greatly in their composition; but it is safe to say that meats, as a rule, have a smaller amount of indigestible nutrients, more protein and fat, and practically no carbohydrates. This means that they are more completely digested and furnish more of the material needed for tissue-building in the body. They also supply a good amount of fat, but not in such large proportions that unless large amounts of fat meat such as pork or bacon were eaten the body could get all the fuel it needed from them without getting a superfluous amount of protein. A diet of

meat and animal fat only seems suited to the Eskimo and others who live in polar regions, but is not wholesome or practical for temperate and warm climates. Hence the ordinary custom of living on a mixed diet of meats, or nitrogenous foods, and vegetables, or carbonaceous foods, is very sensible because it furnishes sufficient of both building material and fuel without loading the digestive organs with a great excess of either.

When we compare the meat of poultry with that of beef, veal, lamb and pork, we find that, in general, the refuse in poultry is slightly less than in the other meats. The amount of refuse, however, varies somewhat with the tastes and habits of the consumer. Cocks' combs and chicken feet are used for broth and other purposes in some parts of Europe, but are usually thrown away by us. Some persons enjoy eating the crisp skin of well roasted birds, while in other families it is discarded as undesirable. If the carcass is boiled for broth much of the nutritious material in the bones, which would otherwise be quite useless, is cooked out and saved from waste. In these and other ways it may be seen that the amount of actual refuse from poultry is a variable quantity. The figures representing the refuse in the accompanying tables include only the bones, as the head, feet, and entrails were removed from the birds before analysis. If the amount of refuse in poultry is in general somewhat less than in the other meats, the amount of water it contains is, on the average, slightly more. The difference in the amount of indigestible nutrients in the two classes is surprisingly small, on the average one-tenth of one per cent. less in poultry than in beef, veal and mutton. Reckoning these differences together we find that about 1 per cent. more of the poultry is actually available to the body than of the other meats. On the average, from 2 to 3 per cent. more of protein is furnished to the body from poultry than from the others and slightly more ash. But while poultry shows a slight superiority in these respects, in fuel value it is slightly inferior, as on the average it contains a smaller proportion of fat. To state these facts in another way, a slightly larger proportion of the material purchased in poultry is actually used by the body and furnishes a slightly greater proportion of the tissue-forming substances, but slightly less of the materials which give energy and heat. These differences are very small indeed when

applied to the amount of meat ordinarily eaten at a meal and might easily be counterbalanced by the tenderness or toughness, the fatness or leanness of a particular specimen or by the mode of cooking.

What has been said in the last paragraph refers of course to the differences between poultry in general and the other common meats in general. Let us now see how the different kinds of poultry compare with each other in nutritive value. Our statements must of course refer only to the average composition of birds of a given kind, and when the differences between the two kinds are on the average very slight, it might easily happen that differences in individual specimens might change the aspect of the comparison.

Common fowl—by which we mean here the mature birds—contain a little more refuse than the average poultry, a little less water, and about the average of indigestible nutrients; it is about like the average in protein and richer than most in fat. Chicken (birds under one year of age) contains about the same proportion of refuse as fowl, noticeably more water and slightly less indigestible nutrients. It contains about the average amount of protein, but is poor in fat and has a correspondingly low fuel value. Capon has about the same proportions of ingredients as fowl. Turkey has comparatively little water and indigestible nutrients, and is rich in both protein and fat. Guinea-hen contains large proportions of refuse and water, is rich in protein but poor in fat.

The poultry game-birds, pheasants and quail, contain rather small percentages of refuse, large amounts of water, and small proportions of indigestible nutrients; they are rich in protein and poor in fat.

Curiously enough, squabs, as the young of pigeon are called, differ from the average composition of poultry reversely from pigeon; where they are poor, pigeons are rich, and vice versa. Squabs contain more refuse and less water than the average poultry, have a high percentage of indigestible nutrients, are rich in protein and poor in fat. On the other hand pigeons contain little refuse, large amounts of water, comparatively little of indigestible nutrients, a good deal of protein and comparatively little fat.

The analyses of goose and green goose show little refuse and water, almost the largest percentages of indigestible nutrients, little protein and large quantities of fat; because of this excessive fat they have a higher fuel value than any other meats except duckling and fat pork.

Duck and duckling both contain comparatively large amounts of refuse, small amounts of water, large percentages of indigestible nutrients, little protein and large quantities of fat. According to these figures duckling contains more fat than any other kind of poultry, almost one-fifth more than chicken.

From these somewhat complicated details we may make a few general statements. The light-fleshed birds (fowl, turkey, guinea-fowl, pheasant and quail) are ordinarily richer in protein and poorer in fat than the dark-fleshed. On account of their low percentage of fat, they show a lower proportion of indigestible nutrients, but also a lower fuel value. In common fowl and perhaps in all light-fleshed varieties the flesh of the young seems to yield a larger proportion of protein and a correspondingly smaller proportion of fat than that of mature birds. In the dark-fleshed kinds, the reverse seems to hold, the young containing less protein and more fat than the old. As a general thing young birds have a smaller, lighter skeleton in proportion to their total weight and therefore show smaller percentages of refuse than the old birds. The young have also a larger proportion of water in their flesh, which may partially explain why it is so much more tender to the teeth.

Some of the differences in the nutritive value of the various kinds of poultry are so large that they ought to be considered in planning dietaries. If green goose with 31 per cent. of fat were replaced by chicken with 6.8 per cent. of fat, or duckling with 11.6 per cent. protein by turkey containing 18.8 per cent. protein, the proportion of fuel and tissue building material furnished to the body might be noticeably changed. On the other hand it would be foolish to insist on the very slight differences between closely-related birds like turkey and chicken or duck and goose. Such differences would hardly be noticeable in the ordinary mixed diet and, as was observed in comparing poultry with other meats, the differences may vary with individual birds, or there may be greater losses in cooking to counterbalance

advantages in the original composition. Very often, too, the price of different birds varies enough to offset the slight differences in composition.

There are a great many interesting theories as to the especial worth or worthlessness of different parts of the flesh of poultry. For example, it is often held that while the breast of duck is very nutritious and wholesome the rest of the bird is hardly fit to eat. This may be partly due to the old prejudice against duck-meat, but there is a small grain of truth in it. In the figures in Table 27 it appears that the breast-meat of duck contains 4.7 per cent. more protein and 22.6 per cent. less fat than the other edible parts. If, as is commonly supposed, cooked fat is less digestible than the other nutrients of food, meat from the breast would of course need less labor of digestion than the other parts, and would also furnish more protein from the same weight of food, and would really be a better food, especially for persons with weak digestions.

One often hears it said that the light meat of fowl, turkey, etc., is more nutritious or more easily digested than the dark. Table 27 shows that the light portions of these meats do contain a little more protein and less fat than the dark, and may therefore yield more nourishment for the same amount of digestive effort. But this difference, as far as it may be definitely stated, seems to depend on the chemical composition of the different parts, and not, as many have maintained, on the texture of the meat fibres. Light meat is surely more tender to the teeth, and one may reason that it must therefore be more easily acted upon by the digestive juices; but it is equally probable that the fibres of light meat are more closely set than those in the dark meat, and it may be argued with equal plausibility that the dark meat is therefore more easily affected by the juices. There is very little definitely known upon this point, save that the differences are too small to be of importance to any but the weakest digestions. It has been shown by experiment that boiled chicken leaves the stomach more quickly than roasted; hence it seems probable that the mode of cooking makes more difference in the digestibility than the very slight differences of composition or textures.

The price of poultry of course varies with the season and with the markets. Early "broiler" chickens, green geese and ducklings bring much better prices than the birds of the same age later in the season, or the older birds of the same kind. Poultry is usually dearer in the East and North than in the South and West and there are, of course, great differences in the prices charged in the various retail markets of the same place. Table 28 shows average wholesale prices of the four most common kinds of poultry for three summer and three winter months. That the differences between summer and winter prices are so slight is doubtless due to cold storage dealers, who buy up poultry when there is an abundance on the market, and keep it until there is a scarcity.

TABLE 28.

Average wholesale prices of poultry per pound at different seasons.

KIND OF POULTRY.	June.	July.	August.	December.	January.	February.	Average.
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
Common fowl,	11	12.0	11.0	11.0	11	12	11
Turkey,	12	13.0	15.0	14.0	15	15	14
Duck,	10	11.5	14.0	13.5	14	14	13
Goose,	8	10.0	9.5	12.0	11	11	10

Of course it is impossible to estimate exactly the average retail prices of poultry for all seasons and all sections, but the figures used in calculating Table 29 represent those prices with something approaching correctness. It is intended to show the cost of the actual nutrients of the various materials when the latter are bought at the prices given in the first column. The second and third columns give the cost of a pound of digestible protein and fat, and the third, the cost of 1,000 calories of energy. The last four columns show the amount of nutrients and energy which ten cents will buy, at the given prices per pound. The refuse, water and indigestible nutrients have been counted out and these figures refer only to the actual nutrients—the material which might actually nourish the body.

TABLE 29.

Cost of digestible nutrients per pound and available energy per 1000 calories and amounts of digestible nutrients and available energy furnished for 10 cents by poultry at certain prices per pound.

FOOD MATERIAL.	Price per pound.	COST PER LB.		Cost per 1000 calories of energy.	AMOUNTS FOR 10 CENTS.			
		Protein.	Fat.		Total wieght.	Protein.	Fat.	Energy.
	Cts.	Dollars.	Dollars.	Dollars	Lbs.	Lbs.	Lbs.	Cal.
Fowl, - - -	15	.90	.97	.15	.67	.11	.10	665
Fowl, - - -	18	1.08	1.17	.18	.56	.09	.09	550
Fowl, - - -	20	1.20	1.30	.20	.50	.08	.08	500
Roasting chicken, -	20	1.16	2.94	.31	.50	.09	.03	320
Roasting chicken, -	25	1.45	3.68	.39	.40	.07	.03	255
Roasting chicken, -	38	2.20	5.59	.60	.26	.05	.02	170
Capon, - - -	28	1.63	1.69	.26	.36	.06	.06	385
Turkey, - -	23	1.25	1.49	.22	.43	.08	.07	450
Turkey, - -	28	1.52	1.82	.27	.36	.07	.05	370
Duck, - - -	25	1.68	1.64	.26	.40	.06	.06	380
Duckling, - -	30	2.59	1.13	.22	.33	.04	.09	460
Goose, - - -	20	1.39	.83	.15	.50	.07	.12	665
Goose, - - -	28	1.94	1.16	.21	.36	.05	.09	475
Green goose, - -	29	2.18	.94	.18	.34	.05	.11	550
Guinea hen, - -	19	1.01	3.73	.32	.53	.10	.03	315
Pheasant, - -	100	4.78	25.00	1.70	.10	.02	—	60
Quail, - - -	40	1.85	6.90	.59	.25	.05	.01	170
Pigeon, - - -	18	.94	2.00	.23	.56	.11	.05	425
Squab, - - -	58	3.82	3.28	.54	.17	.03	.03	185
Beef, loin, - -	25	1.56	1.48	.25	.40	.06	.06	410
Beef, shoulder clod,	12	.75	1.43	.17	.83	.13	.08	595
Mutton, leg, - -	20	1.37	1.38	.22	.50	.07	.07	445
Pork, loin, - -	12	.92	.46	.10	.83	.11	.19	1035
Pork, salt, fat, -	12	6.67	.14	.03	.83	.02	.68	2950
Cod, fresh, dressed,	10	.93	5.00	.46	1.00	.11	—	220
Cod, salt, - -	7	.45	1.75	.22	1.43	.22	.01	465
Eggs, 24c. per doz.,	16	1.39	1.72	.26	.63	.07	.06	385
Milk, 6c. per qt., -	3	.94	.75	.10	3.33	.11	.13	1030
Butter, - - -	25	25.00	.29	.07	.40	—	.32	1365
Wheat flour, - -	3	.31	3.00	.02	3.33	.32	.03	5440
Bread, wheat, -	6	.77	4.61	.05	1.67	.13	.02	2000
Beans, dried, -	5	.29	2.77	.03	2.00	.35	.03	3040
Potatoes, 60c. per bu.	1	.67	10.00	.03	10.00	.15	.01	2955
Apples, - - -	1.5	5.00	5.00	.08	6.67	.02	.02	1270

By comparing the figures given for poultry with those for other materials at the foot of the table, it will be seen that fowl at low prices is the only kind of poultry which furnishes actual nourishment as cheaply as the cheaper cuts of other

meats. Low-priced chicken and turkey, goose and guinea-hen furnish nutrients about as cheaply as high-priced beef and mutton, and pheasants, quail and squab are much the most expensive foods quoted in the table. At prices like those quoted, then, common fowl is the only kind of poultry which is really economical as compared with other low-priced meats. But families who can afford porterhouse steaks and early spring lamb, can as well afford chicken, turkey, duck and goose, and these will make a most welcome variety in the bill-of-fare. On the farm, where only the cost of care and feed has to be considered, and much of the feed can be supplied by skim milk from the dairy or "scratched for" by the birds themselves, even the more expensive kinds of poultry must often be more economical than beef and mutton or even pork, and they certainly would add greatly to the attractiveness of the table. The more attractive and varied our food, providing it is also wholesome, the more good we can get from it, and it is hard to understand why people living in the country, where poultry can be had cheapest and best, do not more generally appreciate the addition which more common use of the different kinds would give to their diet.

In conclusion it may be said that it would appear that many Connecticut farmers might with advantage and profit raise poultry much more extensively than is now the case, and that their wives could add greatly to the variety and attractiveness of the table without increasing the cost of their food by using the different kinds of poultry more than they now do.

DEHORNING CATTLE.

BY C. L. BEACH.

In the report of the Kansas State Board of Agriculture for 1902, Secretary Coburn makes the following statement: "It is estimated, by those who have paid most attention to such statistics, that not less than two hundred persons in the United States each year are killed or seriously injured by cattle horns, and that by the same means a hundred thousand cattle, horses, and colts and innumerable sheep and swine are annually destroyed; that two-thirds or three-fourths of all the tremendous losses by abortion, especially among cows, if carefully investigated could, directly or indirectly, be traced to the presence of horns."

That horns are a detriment in the feed lot is almost universally admitted. This fact perhaps explains the popularity of the polled breeds of beef animals—the Angus, Galloway, Polled Durham, and Red Poll. In the 1897 report of the Kansas State Board of Agriculture, Sec. Coburn has collated the experiences of some ninety-seven successful feeders of beef animals. One of the points upon which judgment was sought was with regard to the detriment of horns in the feed lot. The replies may be summarized as follows:

Eleven had no opinion or did not report.

One was unfavorable to dehorning.

One reported that he did not practice dehorning.

Eighty-four reported as favoring dehorning for the feed lot, although twelve of this number preferred horns in the pasture. Fifty-three of the eighty-four placed a premium on the dehorned animal. Twenty-nine considered the dehorned animal to be on the average 12 per cent. better; eleven as worth 15 cents more per cwt.; and thirteen considered the dehorned animal worth, on the average, $1.75 more per head.

No statistics of opinion in regard to the detriment of horns in the dairy herd are at hand. There is an almost universal opinion among dairymen, however, that the greater quiet and

comfort attending the absence of horns must result in an increased milk secretion. Confined in smaller quarters and larger droves, the beef steer may, in a given time, cause more discomfort to his mate than the cow to her sisters, but the latter enjoys a longer life in which she may cause injury and damage.

The shrinkage of milk resulting from dehorning a dairy herd, as reported in the following tables, can hardly be considered a formidable argument against the practice in view of the later increased yields that may be expected. In 1898 the average loss of milk was 20 pounds per cow and ⅓ pound of butter-fat. In 1903 the average loss per cow was 70 pounds of milk and less than 2 pounds of butter-fat.

THE EFFECT OF DEHORNING ON MILK AND BUTTER-FAT SECRETION.

During the month of May, 1898, there were twenty-four cows in the college herd. Eleven of this number were dehorned on May 7th, and on May 8th the entire herd were turned to pasture.

TABLE 30.

Individual milk yield of dehorned group in 10-day periods before and after dehorning.

Name of Cow.	Month of lactation.	Milk Flow, 10-day Periods, in Lbs.			
		Before dehorning.	After Dehorning.		
			1st Period.	2d Period.	3d Period.
Holstein,	9	158.8	178.2	181.8	172.5
Francille,	9	90.4	86.6	103.4	101.1
Dolly McBeth,	9	122.8	127.8	125.6	117.8
Fannie,	8	115.5	116.8	110.9	98.8
Coomassie,	2	362.9	368.9	355.9	350.9
Jennie,	4	203.4	188.9	198.9	205.2
Statia,	6	99.7	103.7	102.3	99.1
Cora,	3	229.8	243.7	254.4	252.6
Lena,	2	252.7	267.1	286.3	264.6
Anna,	4	145.5	145.3	158.5	174.5
Olive,	5	173.7	191.4	197.6	203.0
	5½	1955.2	2018.4	2075.6	2040.1
13 cows not dehorned,	6¼	2232.1	2448.7	2445.0	2341.7

TABLE 31.

Individual butter-fat yields of dehorned group in 10-day periods before and after dehorning.

Name of Cow.	Month of lactation.	Butter-fat, 10-day Periods, in Lbs.			
		Before dehorning.	After Dehorning.		
			1st Period.	2d Period.	3d Period.
Holstein, - - - - - -	9	6.51	7.48	7.74	7.71
Francille, - - - - - -	9	4.97	4.76	4.92	4.82
Dolly McBeth, - - - - -	9	4.60	4.73	4.47	4.41
Fannie, - - - - - -	8	6.40	6.07	5.53	5.54
Coomassie, - - - - - -	2	15.24	15.99	15.79	15.30
Jennie, - - - - - - -	4	9.45	8.87	10:04	9.92
Statia, - - - - - - -	6	4.76	4.66	5.84	5.88
Cora, - - - - - - -	3	9.30	10.23	10.08	10.10
Lena, - - - - - - -	2	13.52	14.00	13.88	13.50
Anna, - - - - - - -	4	6.25	5.81	6.00	5.84
Olive, - - - - - - -	5	9.08	10.31	11.36	11.02
	5½	90.08	92.91	95.65	94.04
13 cows not dehorned, - - -	6¼	108.32	114.80	115.45	113.62

Tables 30 and 31 show the milk and butter-fat yields in pounds, and Tables 32 and 33 the yields in per cent., both before and after the operation of dehorning. The change from stable to pasture conditions after dehorning resulted in increased yields, but the dehorned group did not regain its normal flow, as compared with those not dehorned, until the end of thirty days.

TABLE 32.

Milk yield of both groups in per cent.

Group.	Mo. of lactation.	Before dehorning.	After Dehorning.		
			1st Period.	2d Period.	3d Period.
		%	%	%	%
Dehorned, 11 cows, - - - - -	5½	100.0	103.2	106.1	104.3
Not dehorned, 13 cows, - - -	6¼	100.0	109.7	109.5	104.9
	—	—	6.5	3.4	.6

TABLE 33.

Butter-fat yield of both groups in per cent.

Group.	Mo. of lactation.	Before dehorning.	After Dehorning. 1st Period.	2d Period.	3d Period.
		%	%	%	%
Dehorned, 11 cows, - - - - -	5½	100.0	103.1	106.1	104.4
Not dehorned, 13 cows, - - - -	6¼	100.0	105.9	106.6	104.9
	—	—	2.8	.5	.5

TOTAL LOSS IN MILK YIELD OF 11 COWS.

1st 10 days, - - -	1955.2 lbs. milk × 6.5% =	127.08 lbs.
2nd 10 days, - - -	1955.2 lbs. milk × 3.4% =	66.47 lbs.
3rd 10 days, - - -	1955.2 lbs. milk × .6% =	11.73 lbs.
		205.28 lbs.

TOTAL LOSS IN BUTTER-FAT YIELD OF 11 COWS.

1st 10 days, - - -	90.08 lbs. fat × 2.8% =	2.52 lbs.
2nd 10 days, - - -	90.08 lbs. fat × .5% =	.45 lbs.
3rd 10 days, - - -	90.08 lbs. fat × .5% =	.45 lbs.
		3.42 lbs.

On May 9, 1903, nine cows were dehorned. On May 16 the herd was turned to pasture. Tables 34 and 35 show the milk and butter-fat yields of the individuals that were dehorned and the totals compared with the yields of the rest of the herd, not dehorned, and Tables 36 and 37 show the yields in per cent. The yields are recorded in periods of seven days and include two periods under stable conditions, one the week before and one the week after dehorning, and five following periods under pasture conditions.

Table 34.

Individual milk yield of dehorned group, in 7-day periods, before and after dehorning.

Name of Cow.	Mo. of lactation.	Milk Flow in 7-day Periods.						
		In Stable.		In Pasture.				
		Before.	After.	After.	After.	After.	After.	After.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Mina, - - -	2	208.4	193.1	203.7	209.2	213.5	214.4	207.4
B. Bell, - - -	6	158.0	61.1	104.5	141.5	157.8	134.1	142.4
Stelline, - - -	6	80.9	73.7	86.5	88.3	91.1	93.5	89.5
Fay M., - - -	5	184.4	157.6	157.0	171.1	200.9	204.1	187.1
Euratas, - - -	5	121.8	113.5	114.0	129.7	136.2	140.6	140.0
Molly, 2d, - -	2	102.4	105.7	120.7	130.1	116.8	123.4	123.5
Brownie, - - -	2	89.0	82.8	83.6	92.3	93.3	90.3	90.2
Copper, - - -	4	115.1	110.6	120.7	131.2	136.1	131.6	128.6
R. Butterfly, - -	6	80.1	82.2	99.8	113.8	115.2	114.2	104.0
	4¾	1140.1	980.3	1090.5	1207.2	1260.9	1246.2	1212.7
Group (8) not dehorned,	6	1009.8	1031.7	1104.3	1157.8	1193.0	1187.4	1119.6

Table 35.

Butter-fat yield of individuals of dehorned group, in 7-day periods, before and after dehorning.

Name of Cow.	Butter-fat Yield in 7-day Periods.						
	In Stable.		In Pasture.				
	Before.	After.	After.	After.	After.	After.	After.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Mina, - - - - -	8 33	8.49	8.55	8.57		9.64	9.44
B. Bell, - - - - -	6.63	4.27	5.22	6.65		6.16	6.01
Stelline, - - - - -	3.23	3.24	3.63	3.62		3.83	3.80
Fay M., - - - - -	6.26	5.67	5.33	5.98	Estimated.	7.33	7.02
Euratas, - - - - -	5.11	5.67	5.47	6.22		6.46	6.22
Molly, 2d, - - - -	4.91	5.28	5.79	6.11		6.29	6.06
Brownie, - - - - -	4.62	4.63	4.59	5.07		5.23	5.17
Copper, - - - - -	6.90	7.07	7.24	7.87		8.68	8.38
R. Butterfly, - - -	5.60	6.65	7.38	8.07		7.42	7.28
	51.59	50.97	53.20	58.16	59.60	61.04	59.38
Group (8) not dehorned, -	49.11	51.35	54.09	56.64	58.99	61.34	57.99

TABLE 36.

Milk flow of both groups in per cent.

Group.	Milk Flow in 7-day Periods. In Stable. Before.	In Stable. After.	In Pasture. After.	After.	After.	After.	After.
	%	%	%	%	%	%	%
Dehorned, 9 cows, - -	100.0	85.9	95.6	107.6	110.6	109.3	106.3
Not dehorned, 8 cows, -	100.0	101.1	109.3	114.6	118.1	117.5	110.8
		15.2	13.7	7.0	7.5	8.2	4.5

TABLE 37.

Butter-fat yield of both groups in per cent.

Group.	Butter-fat Yield in 7-day Periods. In Stable. Before.	In Stable. After.	In Pasture. After.	After.	After.	After.	After.
	%	%	%	%	%	%	%
Dehorned, 9 cows, - -	100.0	98.8	103.1	112.7	115.5	118.2	115.1
Not dehorned, 8 cows, -	100.0	104.5	110.1	115.3	120.0	124.9	118.1
		5.7	7.0	2.6	4.5	6.7	3.0

TOTAL LOSS IN MILK YIELD OF 8 COWS.

1st week, - - - - -	1140.1 × 15.2% =	173.2 lbs.
2nd week, - - - - -	1140.1 × 13.7% =	156.1 lbs.
3rd week, - - - - -	1140.1 × 7.0% =	79.8 lbs.
4th week, - - - - -	1140.1 × 7.5% =	85.5 lbs.
5th week, - - - - -	1140.1 × 8.2% =	93.4 lbs.
6th week, - - - - -	1140.1 × 4.5% =	51.3 lbs.
		639.3 lbs.

TOTAL LOSS IN BUTTER-FAT OF 8 COWS.

1st week, - - - - -	51.59 × 5.7% =	2.94 lbs.
2nd week, - - - - -	51.59 × 7.0% =	3.61 lbs.
3rd week, - - - - -	51.59 × 2.6% =	1.34 lbs.
4th week, - - - - -	51.59 × 4.5% =	2.32 lbs.
5th week, - . - - -	51.59 × 6.7% =	3.45 lbs.
6th week, - - - - -	51.59 × 3.0% =	1.54 lbs.
		15.20 lbs.

The shrinkage in the milk flow of dairy cows as the result of dehorning has been observed by other experiment stations as follows:

Wisconsin Experiment Station, 10 cows dehorned, milk loss 16% for 2 days.
Minnesota Experiment Station, 9 cows dehorned, milk loss 7% for 3 milkings.
Tennessee Experiment Station, 19 cows dehorned, milk loss 1.2% for 10 days.
Cornell Experiment Station, 5 cows dehorned, milk loss 1 lb. per day 4 days.
N. Dakota Experiment Station, 14 cows dehorned, milk loss ½ lb. per day 2 days.

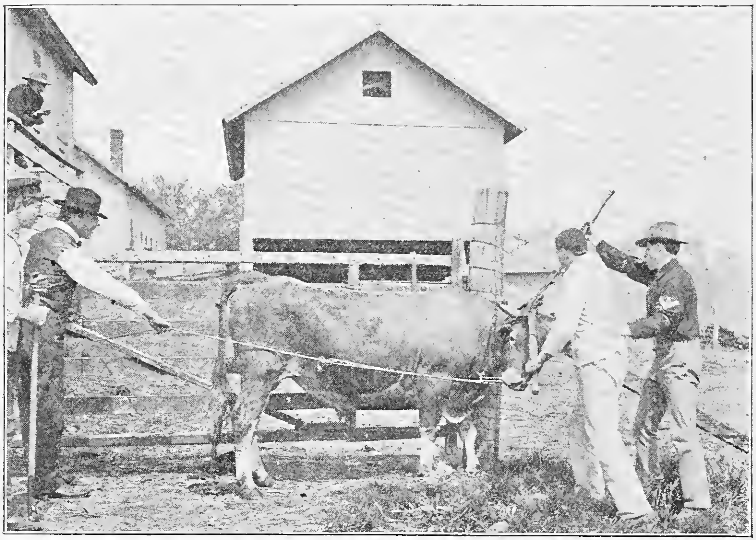


FIG. 7. OPERATING WITH KEYSTONE DEHORNER.

The pain of the operation of dehorning has been overestimated, and the mortality is practically nothing. The shrinkage in the milk and butter-fat yields of dairy cows is small and temporary. The worry, pain, and cruelty of animals to their mates is eliminated when these instruments of torture are removed, and the lack of fear and the quiet contentment of the individuals of the herd are at once noticeable. The benefits from dehorning dairy cattle cannot be accurately measured, but there is an almost unanimous opinion in its favor among those who have practiced it in their herds.

MILKING RECORDS.

BY C. L. BEACH.

One of the obstacles to successful dairying is the inability to secure competent milkers. The first question asked of an applicant for a position upon a dairy farm is, "Can you milk?" A young man who answered the above question by saying that he had always milked at home was engaged at the college farm. At the end of a week the milk records showed a shrinkage of 12 per cent. in the amount of milk secured from six cows which had been assigned this man to milk. An investigation followed, and at the close of the next milking these six cows were immediately milked a second time, and the following amounts of milk were obtained:

Rob Butterfly,	3.3 lbs.
Prehaps,	2.5 lbs.
Rob Butterfly, 2nd,	3.4 lbs.
Rose, 2nd,	5.65 lbs.
Petite,	2.7 lbs.
Jane S,	4.8 lbs.
Total,	22.35 lbs.

This milk tested 10.6 per cent. and contained 2.36 pounds of fat. At another time six cows milked by one individual made a shrinkage of 70 pounds in seven days, while the rest of the herd held their own. These and other similar experiences suggest the value of dairy records. Marked shrinkages like the above might be noticed in the pail, but smaller variations might go unnoticed where a record is not kept. While it is important to keep an individual record of the milk flow of each cow, that the owner may know at the end of the year which are the profitable and which the unprofitable cows in his herd, the same record may serve as a check upon the milkers. If John, James, and Julius milk six cows each, the record of the milkers might be kept as follows:

Yield of milk.

	July 1-7.	July 8-14.	July 15-21.	July 22-28.
Yield of John's cows, pounds, - - -	840	848	876	892
Yield of John's cows, per cent., - -	100%	100.9%	104.3%	106.2%
Yield of James's cows, pounds, - -	1000	968	940	880
Yield of James's cows, per cent., - -	100%	96.8%	94.0%	88.0%
Yield of Julius's cows, pounds, - -	784	820	836	864
Yield of Julius's cows, per cent., - -	100%	104.6%	106.1%	110.2%

A record of this kind should tend to check carelessness in milking; and if prizes were offered, the milkers would have a stimulus to do their best. The increased flow of milk would offset many times over the cash value of the prizes.

Our alumni have for several years offered prizes to the graduating class for proficiency in practical agriculture. In preparation for this contest a score card was devised by the writer for judging efficiency in milking. This score card is introduced here with the results of a preliminary test. The points covered by the score card indicate that the "art" of milking may be supplemented by some scientific knowledge. Five boys took part in the contest. Each boy milked the same five cows three days in succession, and the trial, therefore, covered 15 days.

	Regular Milker.	Contestants.				
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Oct. 1-3.	Oct. 4-6.	Oct. 7-9.	Oct. 10-12.	Oct. 13-15.	Oct. 16-18.
Amount of milk secured, lbs.	311.6	311.1	332	343.6	343.9	325.0
Per cent. of milk secured, -	100.0	100.0	107.0	110.0	110.0	105.0
Amount of fat secured, lbs.,	14.33	14.49	15.00	16.14	15.81	15.60
Per cent. of fat secured, -	100.0	101.1	104.6	112.6	110.3	108.8
Total minutes late or early, -		0	7	43	41	6
Rate of milking, min. per cow,		10.2	10.4	10.6	10.5	10.2
Germ content of milk per cc.,		1438	1604	388	863	275
Germ content of milk of rest of herd per cc., - -		6150	2167	2900	975	2038

This table presents several points of interest: Four milkers increased the milk flow 7, 10, 10, and 5 per cent. respectively, and the butter-fat yield was increased 1.1, 4.6, 12.6, 10.3, and 8.8 per cent. These milkers were familiar with Dr. J. Hengerveld's theory of manipulation of udder after the ordinary flow has ceased. This is the probable explanation of the increased production over the 3-day period preceding the contest.

The rate of milking may appear to be slow, but each milker dressed for milking, brushed his cows before milking, washed his hands, dampened the flank and udder of the cow, rejected the fore milk, milked the cow in a covered pail, weighed, sampled, and secured the yield in the time given.

The germ content of the milk drawn by the regular milkers during the same time is satisfactorily low, but the contestants in each case secured a lower germ content. The samples from the milk drawn by the regular milkers showed an average of 2846 germs per cubic centimeter, and the average of the samples from the milk drawn by the contestants was 914 per cubic centimeter.

The following score card we have used in judging the efficiency of students in milking.

A TEST FOR JUDGING THE EFFICIENCY OF MILKING.

A.	1.	Regularity of Milking,	3
	2.	Rapidity of Milking,	12
	3.	Thoroughness of Milking,	12
	4.	Quietness while Milking,	3
B.	1.	Amount of Milk produced by Cows,	15
	2.	Amount of Fat produced by Cows,	3
	3.	Accuracy of Weighing,	1
	4.	Accuracy of Recording,	1
	5.	Accuracy of Sampling and Babcock Testing,	10
C.		Sanitary Milking.	
	1.	Concerning the Milker:	
		(a) Milker should wear a clean white suit,	2
		(b) Milker must have clean hands,	2
		(c) Milking with dry hands,	2
	2.	Concerning the Cow:	
		(a) Preparation of Cow for Milking,	8
		(b) Prevention of Contamination while Milking.	
		Wipe flank and udder of cow with damp cloth,	2
		Reject fore milk,	2
		Use of covered milk pail,	2
	3.	Determination of Germ Content of Milk.	
		(a) Number of Germs,	20
		Total,	100

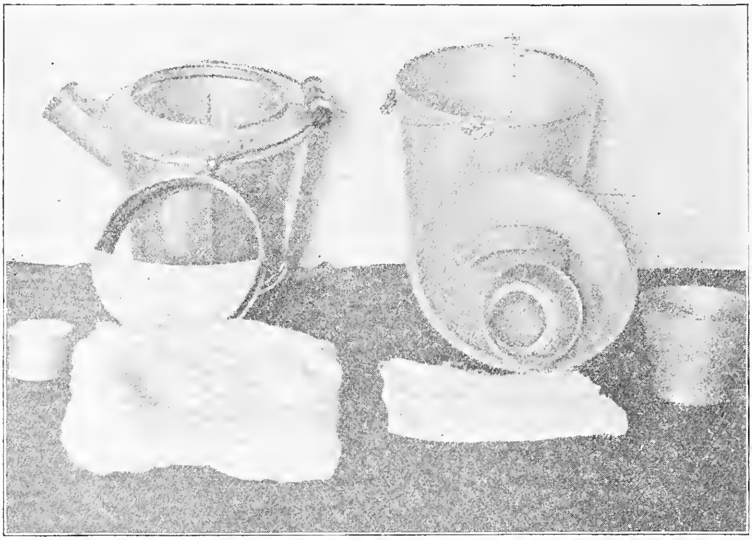


FIG. 8. COVERED MILK PAILS. "GURLER" PAIL ON RIGHT, "STADTMULLER" ON LEFT.

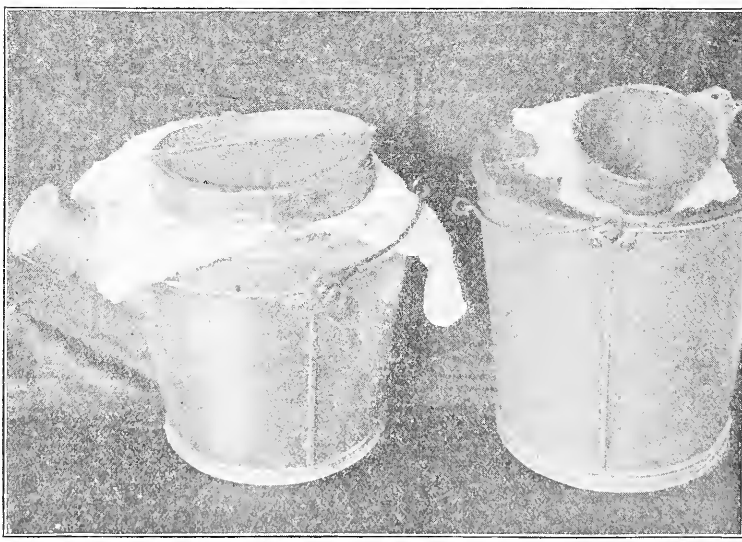


FIG. 9. COVERED MILK PAILS. "GURLER" PAIL ON RIGHT; "STADTMULLER" ON LEFT.

THE FOOD COST OF RAISING CALVES.

BY C. L. BEACH.

For several years records have been kept of the food consumed by calves from birth until about six months old. In 1899 new milk was fed for about four weeks, when skim milk was substituted; but in 1900 this change was made when the calves were less than two weeks old. Rowen hay was kept before them at all times. No grain was fed in 1899, but in 1900 grain was used during the last two months. These calves were designed for the future dairy herd and were fed with that idea in view. The ration was bulky, palatable, with sufficient protein and mineral matter, and with no tendency to cause the animals to lay on fat. The gains of 1¼ and 1⅓ lbs. per calf per day were satisfactory. "A calf designed for a model dairy cow should not gain more than 1½ lbs. per day for the first four months, and less thereafter."*

TABLE 40.

Food consumed by two lots of eight and nine calves for a period of 180 to 191 days.

Animal.	Weight at birth.	Amount Fed.				Age at end of period.	Weight at end of period.
		New milk.	Skim milk.	Hay.	Grain.		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Days.	Lbs.
No. 1, - - -	60	92	4202	579	156	233	342
No. 2, - - -	63	56	4188	609	156	228	374
No. 3, - - -	50	67	3398	331	138	200	317
No. 4, - - -	63	62	3414	260	116	190	270
No. 5, - - -	62	64	3503	418	142	190	311
No. 6, - - -	48	89	2436	316	120	158	241
No. 7, - - -	68	88	1833	129	88	129	206
No. 8, - - -	57	113	1501	96	36	119	185
No. 9, - - -	60	181	2536	273	191	176	311
Average, - -	59	90	3001	337	127	180	284
Avg. 8 calves, 1899,	65	220	2908	619	0	191	315

* Henry's Feeds and Feeding.

FOOD COST OF RAISING CALVES TO SIX MONTHS OF AGE.

	1900 Avg. of 9 Calves.	1899 Avg. of 8 Calves.
New milk at 2½c. per qt.,	$1 02	$2 55
Skim milk at 25c. per cwt.,	7 50	7 27
Rowen hay at $10 per ton,	1 68	3 09
Grain at $20 per ton,	1 27	
	$11 47	$12 91
Gains per day,	1.25 lbs.	1.31 lbs.
Cost per week,	44.6 cents.	47.3 cents.

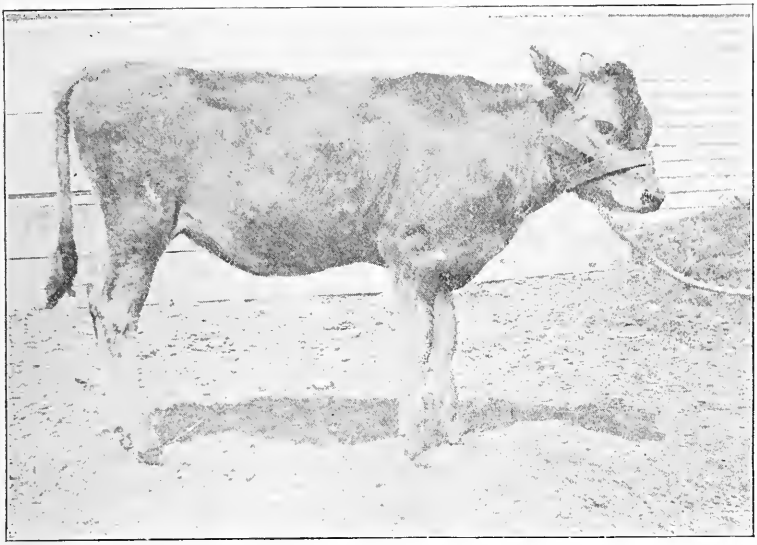
The New Hampshire Experiment Station fed 8 calves, weighing 81 lbs. on the average at the start, for a period of 17.7 weeks. Adopting prices to correspond with our own, the cost is as follows:

209 qts. new milk at 2½c. per qt.,	$5 22
15958 lbs. skim milk at 25c. per cwt.,	39 89
251¼ lbs. flax at $3.25 per cwt.,	8 16
104 lbs. oats at $30 per ton,	1 56
907 lbs. middlings and bran at $20 per ton,	9 07
41½ lbs. linseed at $30 per ton,	63
112 lbs. mixed grain at $20 per ton,	1 12
116 lbs. oatena at $20 per ton,	1 16
1262 lbs. hay at $10 per ton,	6 31
	$73 12
Average per calf,	$9 14
Gains per day,	1.35 lbs.
Cost per week,	51c.

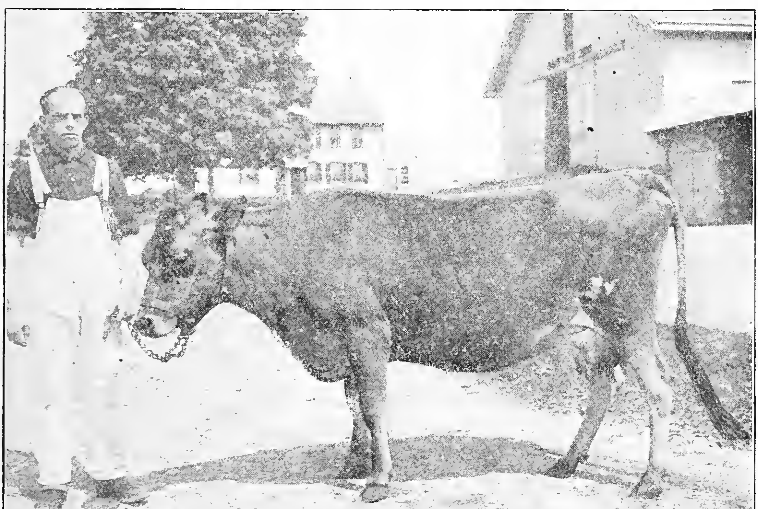
The cost of raising the calves reported in Table 40 from birth to 2 years and 18 days is estimated as follows:

ESTIMATED FOOD COST FROM BIRTH TO TWO YEARS OF AGE.

185 days, as reported above, average of two lots,		$12 19
188 days	at pasture,	2 00
	1 pound of grain per day,	1 88
181 days in stable at 50c. per week,		12 93
194 days	at pasture,	3 00
	120 pounds grain previous to calving,	1 20
Cost at age of 2 years and 18 days,		$33 20

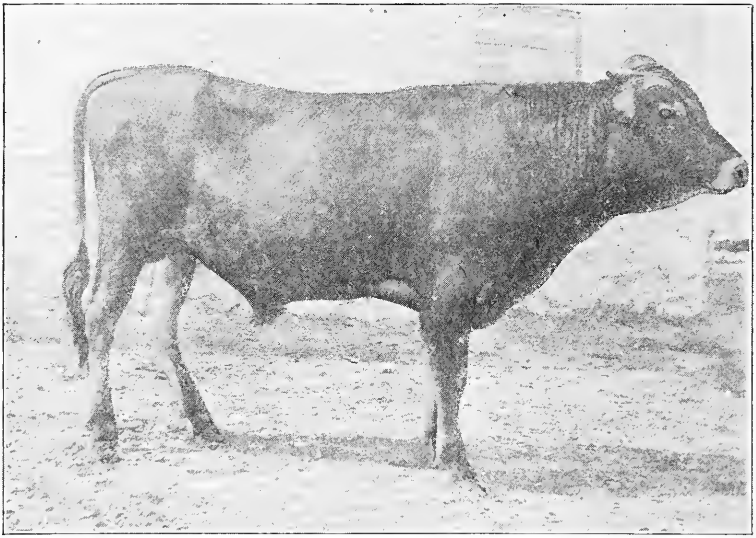


ROBIN BUTTERFLY—RAISED ON SKIM MILK.

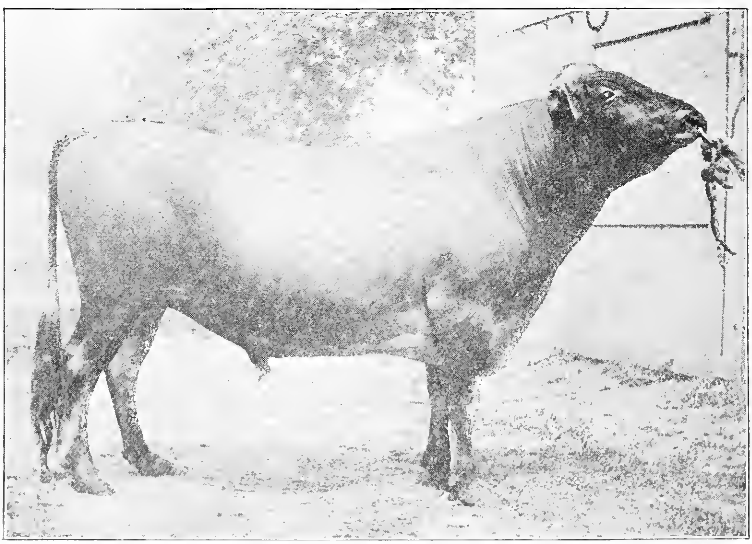


ROBIN BUTTERFLY IN 6-YEAR-OLD FORM.

Average production for first four periods of lactation, 348 pounds of butter.



COPPER STORRS—RAISED ON SKIM MILK.



COPPER STORRS AT MATURITY—A PREPOTENT SIRE.

Record of dam—Average production for 5 years, 445 pounds of butter.
Record of sire's dam—15 pounds, 10 ounces butter in 7 days.
Record of sire's great dam—18 pounds, 12 ounces butter in 7 days.

METEOROLOGICAL OBSERVATIONS AT STORRS AND GENERAL WEATHER AND CROP REVIEW.

REPORTED BY W. A. STOCKING, JR.

During the past year the Station has continued its meteorological observations as in previous years. The equipment at the Station consists of the ordinary instruments for recording temperature, air pressure, air moisture, rainfall, and snowfall. These instruments are similar to those in use by the Weather Bureau of the U. S. Department of Agriculture. An anemometer has recently been added to the Station equipment, so that records of wind velocity will now be made. A summary of the observations made at Storrs during 1902 is given in Table 42.

In addition to the records made at Storrs, the rainfall for the growing season, May to October inclusive, has been recorded by a number of farmers in different parts of the state in coöperation with the Station. The observations made by these men, together with a number furnished by the New England Meteorological Society, are given in Table 41.

The total precipitation for the year, as recorded at Storrs, was 52.12 inches. This is a little over five inches more than the average for the past fourteen years. There have been but two years during the last fourteen when the rainfall has exceeded this amount. In 1897 the total precipitation was 53.03 inches, and in 1901 it was 66.51 inches. The rainfall was unusually great during February, March, July, and September and was unusually light during May and November.

The temperature during the spring months was somewhat higher than the normal, and this, together with the frequent rains, usually in the form of showers, was exceptionally favorable for early growth of farm crops, so that the season was somewhat ahead of the normal during March and April, but the cool nights and lack of rain during May brought it back to about normal by the first of June. The unusual amount of

rain during July greatly retarded haying, so that in many sections of the State much hay was injured by over ripeness and rain during harvesting. The average temperature for January was about 2° below the normal, for February it was normal, for March and April considerably above normal. May and June were about normal, while July, August, September, and October were slightly below the normal. November was about 5° above, with December 6° below, the average for the last fourteen years.

The last killing frost at Storrs occurred May 28th, and the first one in the fall October 10th, giving a growing season free from frosts of 135 days, which is 12 days less than the average for the past fourteen years. In many parts of the State the last injurious frost in the spring was May 10th, while at New Haven there was no frost after April 5th. In a small section in the east end of the State the first injurious frost in the fall occurred September 5th, but throughout the greater part of the State vegetation was not injured until the general frost of October 10th.

TABLE 41.

Rainfall during six months ending October 31, 1902.

Locality.	Observer.	Inches per Month.						Total.
		May.	June.	July.	August.	September.	October.	
Canton,	G. J. Case,	1.44	4.20	7.71	3.73	7.15	6.11	30.34
Clark's Falls,	E. D. Chapman,	—	4.54	3.26	1.12	3.77	—	—
Colchester,	S. P. Willard,	1.55	3.65	4.75	2.10	6.98	5.78	24.81
Cream Hill,	C. L. Gold,	2.99	5.06	9.40	4.70	7.83	5.42	35.40
East Windsor,	J. N. Fitts,	1.67	3.60	4.89	5.94	4.74	—	—
Falls Village,	M. H. Dean,	2.65	4.83	7.40	3.24	8.44	4.96	31.52
Grove Beach,	—	2.01	4.15	3.20	2.43	5.47	5.10	22.36
Hartford,	H. H. Moore,	1.59	5.18	6.85	6.11	6.51	6.71	32.95
Hawleyville,	E. N. Hawley,	2.36	4.19	5.08	3.14	6.25	6.33	27.35
Middletown,	A. P. Bryant,	0.80	4.33	4.28	—	—	—	—
New Haven,	Weather Bureau,	1.61	4.35	3.26	2.14	5.84	6.41	23.61
New London,	J. R. May,	1.76	2.77	2.23	1.63	4.63	4.21	17.23
N. Grosvenor Dale,	Grosvenor D. Co.,	1.45	3.91	7.34	3.59	3.94	5.66	25.89
Norwalk,	G. C. Comstock,	2.60	4.72	2.45	3.09	7.87	7.64	28.37
Southington,	L. Andrews,	1.65	3.70	5.65	3.25	7.70	6.10	28.05
Storrs,	Agr. Exp. Station,	1.59	3.24	7.48	2.17	7.05	5.68	27.21
Torrington,	—	2.01	4.52	8.22	5.39	5.99	5.91	32.04
Voluntown,	Rev. E. Dewhurst,	1.21	3.97	4.19	1.67	5.36	4.67	21.07
Waterbury,	N. J. Welton,	2.01	5.16	4.58	2.82	6.42	6.19	27.18
W. Simsbury,	S. T. Stockwell,	1.61	3.52	7.23	3.50	5.78	6.15	27.79
Lebanon,	E. A. Hoxie,	0.85	4.26	—	—	—	—	—
Average,	—	1.78	4.22	5.37	3.25	6.20	5.82	27.21

TABLE 42.—*Meteorological observations for 1902.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Highest barometer, -	30.71	30.28	30.56	30.30	30.55	30.98	30.41	30.31	30.50	30.57	30.63	30.73	—
Lowest barometer, - -	29.29	28.88	29.14	29.34	28.89	29.35	29.79	29.70	29.70	29.35	28.80	29.49	—
Mean barometer, - -	30.10	29.84	29.96	29.95	29.98	29.90	30.04	29.92	30.09	30.10	30.10	30.12	—
Highest temperature, -	50	52	66	83	87	89	*85	87	84	71	67	54	—
Lowest temperature, -	−1	4	20	26	27	39	†47	45	*34	25	20	−9	—
Mean temperature, - -	24	25	41	46	55	64	66	66	59	48	44	23	—
Relative humidity, - -	—	—	—	—	67	75	86	78	80	73	—	—	—
Total precipitation, inches,	2.53	5.11	6.35	3.81	1.73	3.25	7.48	2.17	7.05	5.68	1.10	5.86	52.12
No. days with .01 inch or more precipitation,	10	8	13	9	10	12	16	8	12	7	7	15	127
No. clear days, - -	12	9	8	7	14	7	8	8	9	11	5	9	107
No. days partly cloudy, -	8	8	11	13	10	14	5	15	6	9	10	5	114
No. days cloudy, - -	11	11	12	10	7	8	18	8	15	10	15	17	142

* Maximum and minimum thermometer broken from 7th to 19th inclusive; these temperatures are those recorded during the rest of the month.
† Maximum and minimum thermometer broken from 9th to 23d inclusive; these temperatures are those recorded during the rest of the month.

TABLE 43.—*Monthly mean temperature for past 14 years.*

YEAR.	January.	February	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.	Mean.
1888, - -	—	—	—	—	—	65.3	66.4	67.3	57.1	43.8	39.7	30.0	—
1889, - -	30.8	22.1	34.9	45.6	58.4	65.2	67.9	64.8	59.7	45.8	40.9	35.1	47.6
1890, - -	32.0	31.7	30.8	44.7	54.9	63.3	67.5	66.0	59.5	47.6	37.9	23.4	46.6
1891, - -	28.8	29.3	31.9	46.1	54.1	63.9	65.2	68.4	63.7	48.3	38.2	37.0	47.9
1892, - -	25.5	26.9	29.9	44.9	53.6	67.0	69.2	67.4	59.1	48.5	37.6	25.5	46.3
1893, - -	17.3	23.5	30.3	42.0	54.5	64.2	67.9	68.0	55.9	51.7	38.1	27.8	45.1
1894, - -	27.7	23.0	38.6	44.7	56.4	66.0	70.9	65.8	63.0	50.6	34.1	28.2	47.4
1895, - -	24.4	19.9	31.1	44.1	57.33	66.65	66.1	68.3	63.1	45.0	41.7	32.63	46.7
1896, - -	21.8	26.3	28.5	47.5	59.9	63.2	69.6	68.5	59.9	47.2	43.5	26.8	46.9
1897, - -	25.0	27.0	34.0	46.0	56.0	62.0	69.0	66.0	60.0	51.0	39.0	31.0	47.2
1898, - -	25.0	28.0	40.0	42.0	54.0	64.0	70.0	69.0	63.0	52.0	38.0	29.0	47.8
1899, - -	25.0	22.0	31.0	45.0	56.0	67.0	68.0	67.0	59.0	52.0	39.0	31.0	46.8
1900, - -	27.0	26.0	30.0	46.0	55.0	66.0	71.0	69.0	64.0	54.0	41.0	29.0	48.2
1901, - -	25.0	19.0	33.0	45.0	54.0	67.0	71.0	66.0	62.0	50.0	33.0	29.0	46.2
Average, -	25.8	25.0	32.6	44.9	55.7	65.0	68.5	67.2	60.6	49.1	38.7	29.8	46.9

TABLE 44.—*Monthly precipitation for the past 14 years.*

YEAR.	January.	February	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total.
1888, -	—	—	—	—	—	2.10	1.93	4.97	8.45	6.35	4.94	5.28	—
1889, -	4.03	1.64	1.96	3.49	2.16	3.50	11.39	3.78	4.00	5.52	5.91	2.88	50.26
1890, -	2.66	3.28	6.12	3.15	6.33	2.79	2.81	4.26	7.19	5.25	0.82	4.21	48.87
1891, -	8.52	5.64	4.42	3.51	2.50	1.84	4.96	3.95	4.08	4.14	3.09	4.96	51.61
1892, -	4.91	1.60	3.00	0.70	5.60	2.77	3.25	5.20	1.40	1.09	5.41	1.35	36.28
1893, -	2.39	5.88	4.67	3.82	7.12	1.98	1.58	3.79	2.58	6.71	2.45	3.68	46.65
1894, -	2.24	3.13	1.18	2.67	3.58	0.59	2.09	2.37	3.01	4.16	4.00	4.31	33.33
1895, -	5.78	0.63	2.62	4.27	2.16	1.78	4.13	3.48	2.97	6.74	6.97	4.12	45.65
1896, -	1.60	7.10	4.86	0.80	2.72	1.78	3.22	2.71	7.03	3.60	2.49	2.67	40.58
1897, -	3.84	3.40	3.66	2.37	4.44	2.79	12.24	5.23	1.39	0.92	7.14	5.61	53.03
1898, -	4.70	4.03	3.09	4.44	3.81	2.48	6.24	5.87	2.22	6.18	6.11	1.96	51.13
1899, -	3.76	3.97	5.58	2.20	1.17	3.72	5.55	3.27	3.31	1.54	2.10	2.14	38.31
1900, -	3.42	7.31	6.43	2.67	4.91	4.32	2.76	2.03	2.27	3.21	6.79	2.22	48.64
1901, -	8.50	1.05	7.18	9.51	6.30	1.96	5.54	7.58	4.33	1.97	3.04	9.55	66.51
Average, -	4.33	3.74	4.21	3.35	4.06	2.46	4.83	4.18	3.87	4.10	4.38	3.92	46.99

TABLE 45.

Growing season for past 14 years.

YEAR.	Last killing frost, Spring.	First killing frost, Fall.	Growing Season.
1888, - - - -	May 16	September 7	114 days
1889, - - - -	May 4	September 23	142 days
1890, - - - -	April 29	September 25	148 days
1891, - - - -	May 5	October 17	164 days
1892, - - - -	April 30	September 21	144 days
1893, - - - -	May 8	October 17	161 days
1894, - - - -	May 15	September 26	134 days
1895, - - - -	May 17	October 15	150 days
1896, - - - -	May 2	September 24	144 days
1897, - - - -	April 22	September 28	159 days
1898, - - - -	May 10	October 17	160 days
1899, - - - -	May 4	September 15	134 days
1900, - - - -	May 11	October 18	158 days
1901, - - - -	May 6	September 26	142 days
Average, - - - -	—	—	147 days

APPENDIX.

Report of the Director

For the Year Ending June 30, 1902.

The subjects of experimental investigation undertaken by the Station during the year 1901–2 were similar to those of previous years. This was in accordance with the policy of the Station since its foundation, namely, to undertake comparatively few lines of work, have these as nearly parallel as practicable, and continue them from year to year as long as circumstances should warrant. The principal inquiries conducted for a number of years had to do with the nutrition of plants, domestic animals and man, and the bacteriology of the dairy. These included experiments on the effects of fertilizers upon the growth and composition of plants, studies of rations fed to milch cows, studies of bacteria, especially those concerned in normal cream ripening, and investigations of the food and nutrition of man.

Inquiries along the various lines were taken up as usual during the year 1901–2, but the work of the Station was interrupted in several ways and part of it had to be terminated in an unfinished condition. Prof. C. S. Phelps, who had charge of all the work done at Storrs, including the investigations with plants and animals, resigned his position as vice director and agriculturist of the Station during the middle of the year; and at the same time it was decided to transfer to Storrs as much as possible of the work that up to that time had been carried on at Middletown. The work at Storrs undertaken by Prof. Phelps during the year could not be completed and consequently there were no results to be reported. The remainder of the work for the year 1901–2, *i. e.*, investigations in nutrition and dairy bacteriology, was carried out without interruption, but some of this, particularly that having to do with the food and nutrition of man, forms a part of consecutive inquiries extending over a number of years, and the results of the work

of any one year have to be considered in connection with those from similar inquiries in other years of which they form a part. Therefore, instead of attempting to prepare the usual annual report, which would include only such work as was completed and could be reported for the year, it seemed best to carry the results along and combine them with the work of the year 1902–3.

The feeding experiments with dairy herds that for a number of years had been carried on by the Station in coöperation with the farmers in different parts of the State, under the direction of Prof. Phelps, were not undertaken during the year 1901–2. The object of these experiments was to learn how representative dairy farmers in Connecticut fed their cows, compare the results obtained by their methods, by the results of other methods elsewhere, and to suggest improvements wherever it seemed advisable. A summary of the work in this line was given in the report of the Station for 1901.

The field and pot experiments with fertilizers upon the growth and composition of plants, including soil tests and soil improvement experiments on field plots and special nitrogen experiments both on field plots and in pots, were taken up as usual by Prof. Phelps in the spring of 1902, but owing to his resignation in June of that year these investigations were not completed.

The work upon the bacteria of milk was continued during the year by Prof. Conn, aided by Mr. W. M. Esten and Mr. W. A. Stocking, Jr. The inquiries conducted under Prof. Conn's direction were a continuation of those of preceding years and the results are included in the reports of Prof. Conn's work in the present publication.

The inquiries on the food and nutrition of man carried on by the Station in coöperation with Wesleyan University and the United States Department of Agriculture were continued during the year. These included analysis of food materials, digestion experiments with men and metabolism experiments with men in the respiration calorimeter. The results of these investigations are given in connection with others in the same lines, as explained in an article on a previous page of the present report.

The expenditures for the year 1901–2 are given on another page in the customary report of the treasurer.

W. O. Atwater, *Director.*

Report of the Treasurer

For the Fiscal Year Ending June 30th, 1902.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.	
United States Treasury,	$7,500 00
EXPENDITURES.	
Salaries,	$4,407 35
Labor,	935 95
Publications,	6 00
Postage and stationery,	329 86
Freight and express,	64 25
Heat, light, water, and power,	354 37
Chemical supplies,	140 90
Seeds, plants, and sundry supplies,	228 18
Fertilizers,	38 26
Feeding stuffs,	10 07
Tools, implements, and machinery,	27 06
Furniture and fixtures,	103 14
Scientific apparatus,	426 92
Live stock,	12 15
Traveling expenses,	91 96
Contingent expenses,	15 00
Buildings and repairs,	308 58
	$7,500 00

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1902, that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $7,500 and the corresponding disbursements $7,500, for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress, approved March 2, 1887.

(Signed,) Geo. A. Hopson, M. M. Frisbie, } *Auditors.*

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS— RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	119 21
	$1, 919 21

EXPENDITURES.

Salaries,	$1,111 13
Labor,	123 91
Postage and stationery,	29 75
Freight and express,	3 25
Heat, light, water, and power,	40 74
Chemical supplies,	21 50
Seeds, plants and sundry supplies,	27 01
Bacteriological investigations,	437 86
Tools, implements, and machinery,	1 15
Furniture and fixtures,	2 90
Scientific apparatus,	93 41
Traveling expenses,	26 60
	$1, 919 21

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1902, that we have found the same well kept and classified as above, and that the receipts for the year from the State of Connecticut are shown to have been $1,800 and that the receipts for the year from miscellaneous sources are shown to have been $119.21, making a total of $1,919.21 receipts, and the corresponding disbursements $1,919.21; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance.

(Signed,) GEO. A. HOPSON, M. M. FRISBIE, } *Auditors.*

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